Intermediate Division
Interim Revision
1972

Ontario Department
of Education

Science

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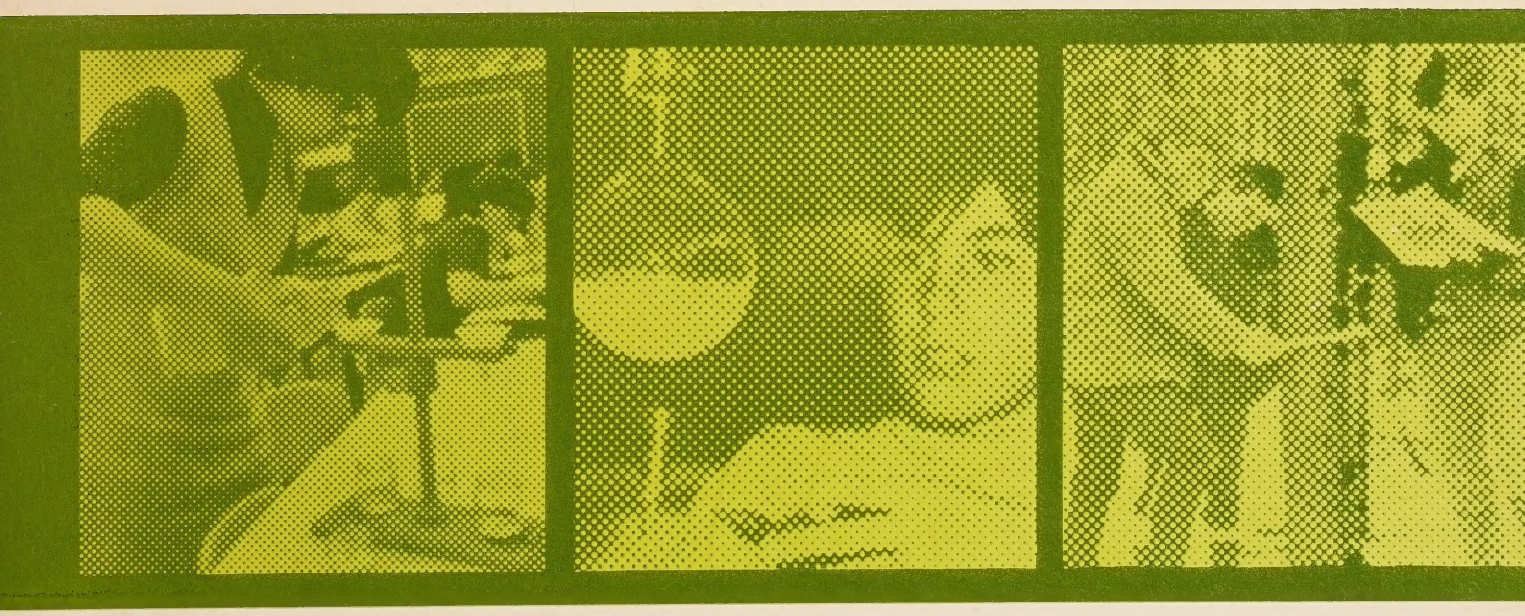

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This guideline is an Interim Revision of Curriculum I:1(e), Intermediate Division Science, pending the cyclic review of the Intermediate Division curriculum guidelines.

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Introduction

This guideline is designed to assist individual teachers and local curriculum committees in developing courses for, and with, students in the Intermediate Division.

During the sixties, major changes took place in education in general, and in science education in particular. The scientific and the teaching communities produced detailed schemes for teaching some topics in science. A spirit of inquiry pervaded more and more classrooms, both in science and in other subjects. New techniques, some sophisticated and some simple, became commonplace in laboratories and in the field. In the post-sputnik era, school children became aware of the dramatic increase of knowledge within the scholar's reach as their courses were brought up to date.

Most important, teachers were making basic changes in philosophy. Universities, secondary schools, and elementary schools became places for dialogue. Programs such as *Man in Society* and *Space and Man* were formulated to cross the disciplines while new programs such as *Biology, Grade 13* fell within the traditional boundaries. Since the publication of the report of the Provincial Committee on Aims and Objectives of Education in the Schools of Ontario, there has been an increasing number of schools where young people are free to determine, along with their teachers, the path of much of their own education.

In order to assist teachers in the development of a science program at the Intermediate Division level in the seventies, the present guideline provides an introduction to three concerns of the curriculum developer for his further study. The first concern is to define the place of science in general education from kindergarten to high school graduation; the second is to describe the objectives of science education for all students in the Intermediate Division; the third is to outline the general nature of the science program in the Intermediate Division in order to help the teacher and his students realize the described objectives.

It is hoped that the thoughts expressed in the following pages will lead to a new dialogue within the schools and to an exchange of ideas and experiences among schools. It is recognized that new programs do not come to life out of printer's ink and paper, but through the development of fresh ideas and a continuing dialogue between a teacher and those around him. Hence, this publication is a resource document intended to provide a rationale for the guidance of teachers and local curriculum committees as they undertake the task of developing a science program for Intermediate Division students.

Science teachers and other science educators are invited to forward suggestions for the revision of this publication, based on their experience of using it as a resource document, to the Department of Education so that future publications may benefit from this broad experience.

The Place of Science in Kindergarten to Senior Division Education

In the present day, it is commonly recognized that education and science cannot be treated separately. In all programs, emphasis is being placed on encouraging pupils to follow their interests to the farthest limit possible within the framework of the program.

Ideally, children now begin their schooling in a subjectless school. Oral language is recognized as the common medium of communication. Other characteristics of newer programs should also be noted. Technical studies are becoming available to all students; both girls and boys are becoming increasingly interested in the changing functions of the family; in the gymnasium and on the playing field, an emphasis on movement is displacing the militaristic kind of exercise and game skill; contemporary problems are often related to similar situations in recorded history; students now seek the whole picture and not just the geographic elements of a region. In all this world of learning, what is the place of science?

The Search for Order

Einstein has defined science as "the attempt to make the chaotic diversity of our sense experience correspond to a logically uniform system of thought."[1] Thus to a scientist, science has one main function: to impart order to a complex world that appears at first sight to be in confusion. He seeks to develop patterns, sometimes called models, and he looks for relationships so that the universe, or at least some segments of it, may become predictable. Then, in whatever way seems suitable, he describes the universe around him. Of course there will be difficulties; problems will arise. A scientist, however, has long experience, he is skillful, he has learned techniques, he has colleagues, he has literature resources in his discipline, and hence may be able to resolve his problems to some extent. Decade by decade, the scientist comes closer to being able to see his universe as a logically ordered system.

Children, too, look for order. Students do not have a repertoire of models to call on. Bit by bit they develop patterns to explain the real world around them. Older students revamp their patterns as they gain more experience in the field, in the laboratory, and in the library. Jean Piaget expresses the process: "Each new level of development is a new coherence, a new structuring of elements which until that time have not been systematically related to each other."[2] In this process of development, the teacher assists the student in gaining an understanding of the model developed by scientists to explain the phenomena being studied. The student is then in a position to discover that the scientists' model explains the observations he has made himself and explains them more effectively than he has been able to do.

Science as a Vehicle for Education

One function of the study of science in the school—the development by students of patterns to explain the world around them—has already been described. In the teacher's mind, however, a principal function of science studies is to serve as an educational tool; it is in this respect that all subjects in the school curriculum serve a common goal. The development of character and personality, of attitudes and skills, of aptitudes and interests is a fundamental goal that transcends in importance the learning of specific subject content.

Science also shares with other subjects opportunities to provide for the development of skills in such basic processes as observing, classifying, measuring and using space-time relationships. In addition, science studies also assist the student to develop his aptitude to infer, to formulate hypotheses, to design experimental situations to test these hyotheses, to recognize variables, to assess data critically and to reason both inductively and deductively.

In both of these areas—the development of personal characteristics and skills of learning and investigation—science serves as a valuable vehicle for the fundamental aims of education.

[1] John H. Woodburn and E.S. Osburn, *Teaching the Pursuit of Science* (New York: Macmillan Co., 1965, p.9). Available in Canada at Collier-Macmillan Canada Ltd., Galt, Ontario.

[2] Eleanor Duckworth, "Piaget Rediscovered", *Journal of Research in Science Teaching*, vol. 2, no. 3 (1964). Reprinted in *Readings in Science Education for the Elementary School*, eds. E. Victor and M.S. Lerner (New York: Macmillan Co.; Toronto: Collier-Macmillan Canada, Ltd., 1967), p.317.

It is generally acknowledged that children are not small adults, but it is not always recognized that a child's world is not the scholar's world. Nor is the child's science the scholar's science, though it may resemble it to a degree.

Younger children rarely meet *science* as a formal subject in the first two years of school. They do meet the real world every day: they observe it, probe it, and ask questions. Day by day, they invent new patterns to explain aspects of the universe that surrounds them. But they live in an integrated world, a world undivided by arbitrary divisions of mathematics, history, language, science, and art.

By the end of the Primary Division, boys and girls can recognize science as an area of study. They recognize certain types of information as being scientific: that deer shed antlers, that granite is made of two or three minerals, that salt dissolves in water, that water expands on freezing, that the moon has craters, and that copper conducts electricity. Science as a discipline is becoming recognizable.

In the Junior Division, science-oriented investigations are frequently selected on the basis of variations in the seasons or as a result of the students' expressed interest in such diverse objects as bicycles and insects or in some current event such as a report of food poisoning. The emphasis is on fostering curiosity in scientific phenomena, on processes involved in conducting investigations, and on an elementary understanding of the topic of study that has interested the child rather than on a more organized, formal approach to science studies. In this division, as in the Primary Division, some teachers are also successful in incorporating scientific investigations into a broader program of studies without giving formal recognition to the study of science.

In the Intermediate Division, science studies are frequently organized into broad areas such as biological science, earth science, and physical science. There is a wide variation in approach and content in Ontario. By comparison, in European countries the formal disciplines of biology, chemistry, and physics are frequently studied concurrently. In recent years a number of schools in Ontario have based a portion of their science program in this division on units of study such as those prepared by the Ontario Institute for Studies in Education. The prepared material serves as a convenient starting point for the pupils' own investigations. In other classrooms, scientific studies are pursued in the context of a general area called *Environmental Science*. Interest has been increasing recently in the educational possibilities that arise when two or more of the traditional disciplines are co-ordinated in the study of a broad theme such as pollution. Science overlaps all the other disciplines; hence allowance for some form of integrated study in the total school curriculum provides for a more natural development of an area of study.

Science in the Senior Division is commonly subdivided into the classical disciplines of biology, chemistry, and physics in order to enable those with special interest to organize a more detailed, systematic, and rigorous science program. Semestered courses in such fields as electronics and microbiology are also offered in certain schools. Curriculum development in such areas as space studies and historical studies of scientific and technological developments are giving science a new relevance and significance for many students who are not committed to a career involved directly with science. In this division, also, the moral implications that must be considered in the application of the scientists' knowledge become an issue of basic concern.

Is science a necessary part of a general education? A hundred years ago this would have been a question of argument, for science had not yet earned a place in the curriculum. The first Ontario school science laboratory was set up in Whitby in 1872.[3] Today, however, science studies form part of every child's curriculum at some stage in his education, and at least a little knowledge of such scientific topics as the trajectories of space vehicles heading for the moon is necessary to comprehend the daily news broadcast. We live in a science-oriented society and our children must become scientifically literate.

While society has its demands, students have theirs. A general education must answer the questions of the young: *Why is a baby born without talk or teeth? Why are people in minority groups often treated differently from those in the majority? Why shouldn't I try drugs?* Science programs aimed at a general education will be able to provide ample opportunity for student-centred programs and still provide the basic education that Everyman needs.

At tertiary levels of education, science studies may become a prerequisite for training in medicine, engineering, or scientific research, but only a small fraction of the school population will enter these fields and look toward science as part of a specialized education. Even for these specialists-to-be, some argue that early specialization is undesirable. This group contends that the kind of school science suitable for a general education is also the kind of science that is the best preparation for tomorrow's specialists. As one university man expressed it, "If the right thing is done for people in high school who are not going on to study science, then automatically the right thing is done for those who are."[4]

The study of science, for the intermediate student and the scientist alike, is basically a search for logical patterns that explain the behaviour of the universe. At the same time, science studies assist the student in developing skills in certain basic modes of scientific thinking which are applicable to many aspects of life. To the educator, however, the most significant aspect of the study of science is the contribution it makes, like any other subject, to the development of the personal characteristics of the boy or girl.

Traditionally, science courses in the Senior Division have been designed to prepare students for further studies in the sciences. More recently, however, science curriculum developments have shown evidence of concern in two directions. The first has been to provide science-oriented students with deeper insight into the logic and methods of the professional scientist; the second has been an attempt to increase the relevance of scientific knowledge to the large majority of students who are not science-oriented.

[3] A.G. Croal, "The History of Science in Ontario 1800–1900" (D. Paed. diss., University of Toronto, 1940).

[4] W.G. Henry, E.P. Hincks and L.R. McNarry, "Pre-university Science Education and the Ottawa Section", *Physics in Canada*, vol. 21, no. 4 (1965), p.37.

Criteria for Science Programs of the Intermediate Division

The Intermediate Division lies in a key position; it forms a bridge between elementary and secondary schools. In fact in some areas there are special intermediate schools for students in their early teens. In 1970 it was the largest single division in the Ontario school system, as the following table indicates.

Enrolment in Ontario Schools
September 1970[5]

Kindergarten	154,465
Primary (1–3)	489,954
Junior (4–6)	471,649
Intermediate (7–10)	612,109
Senior (11–13)	263,126

Education is now recognized as a continuum. Formerly, the administrative structures for elementary and secondary schools were separated, and even teachers looked on themselves not as teachers, but as elementary school teachers or secondary school teachers. As a result, the virtues of the elementary school were not adequately extended into secondary education, and the strengths of the secondary school were inadequately represented in elementary education.

Hence, objectives for science education at the Intermediate Division level should provide goals that are common to the elementary and secondary levels and thus increase the likelihood of the development of a continuum in the educational growth of each student.

Lists of objectives of science education have appeared in various journals and science textbooks for many years. In some recent curriculum projects, objectives are stated in terms of the development of specific intellectual and technical skills. Mager has given useful guidance to teachers interested in defining their objectives in such behavioural terms.[6]

In this publication, however, emphasis is given to broad educational objectives; otherwise, achievements of lesser importance may take precedence over the paramount considerations. The following criteria for curriculum development are among those worthy of careful consideration by science teachers. The list is not complete, nor are the items placed in any order of priority.

Relevance

A student lives now and here. Whatever he studies must seem worthwhile from a short-term, as well as a long-term, perspective. If he feels a commitment to ensure clear streams and clear lakes, he might well study the ecology of fresh water. If nuclear energy is produced in his community, it could be a natural starting point. The beginning of the fishing season may be the time to investigate fish. To learn effectively, a student must be involved in pursuits that have meaning for him.

Responsibility

Young people today are looking to find their place in the world as it is, and yet they expect to have a share in building a brave new world. The science program can include both. The student of the intermediate years should be intensely aware that he is both a natural part of the natural world and a conforming or non-conforming part of his technological environment. Ecology and man, technology and man, are inseparable.

A student does alter his world, however; his actions mould and shape his community. He is responsible in the present and will be responsible for the future. How better can he prepare than by having some share in determining his curriculum?

Literacy

Education is desperately needed for survival, both for the individual and for society. To be literate in these days means more than being able to read and write. Today it would include having some knowledge of the great ideas of science, some understanding of the patterns that man sees in the universe. There are many principles that responsible adults should understand: for example, the principle of the conservation of energy and matter.

Likewise, there are many simple reference facts that can hardly be missed in today's culture: man breathes out more carbon dioxide than he breathes in, table salt contains two elements, rockets operate best outside the atmosphere, electro-magnetic radiation moves at 300,000 kilometers per second.

[5]Data provided by the Statistics Section, Ontario Department of Education.

[6]Robert F. Mager, *Preparing Instructional Objectives* (Palo Alto, Calif.: Fearon Publishers, 1962).

Scientific Processes

Comenius, describing the training of artisans, wrote "They learn to forge by forging, to carve by carving, to paint by painting, and to dance by dancing."[7] Today, parents say that they send their children to school "to learn how to think", not merely to amass information. Encyclopedias and computing machines can store more information and make it more readily available for future use than we can. How does one learn to think?

Comenius would say that science courses should teach children to think by thinking, which can be done in any science course.

At some time, however, students should become aware of what they are doing; they should come to realize that they are employing the processes through which men learn. They should be aware of such processes as description, inference, analysis, generalization, and prediction.

In many of our schools the usefulness of controls has received little attention. The consistent use of this technique of investigation, which is routine with scientists, greatly facilitates the search for regularities as well as the recognition of irregularities. Changes in shades of colour, for example, frequently are not discernible unless controls are used. The claim that a phenomenon occurs only under certain specific observable conditions is worth little unless the evidence provides reasons for believing that the phenomenon does not occur in the absence of these conditions.

Handwork

A pupil learns best when he participates actively in the investigation. He needs to have apparatus and tools, he needs time for direct experience, and he needs practice in developing motor skills. A science course should be centred around laboratory work and other practical activities so that children may have opportunities to be as proud of their hands as of their minds. It should not be supposed that, just because most students of the Intermediate Division are able to work through *formal operations*, according to Piaget, their programs should be divorced from the *concrete operations* so characteristic of the Junior Division.

Interdisciplinary Relationships

Education can become a lifelong search for a comprehensive understanding in which there are no artificial compartments of school subjects. At times the subject *Science* should melt away completely so that a student may be able to study segments of his real world in a natural fashion. How can a student feel that he has freedom to do a scholarly study of the Holland Marsh if he must stop at ethnic origins because that is history, or neglect contour lines because that is geography? Quite likely in the area of science he will investigate soil, weather, the carrots, the celery, and the pesticides. At the fringes of science, however, all the disciplines may be encountered. As has been said, "We need a wisdom that integrates rather than a learning that divides."

Clearly, there should be a place for interdisciplinary thinking as well as a place for studies along the traditional lines of the disciplines.

Self-evaluation

The design of the course and teaching practices should make it possible for students to criticize their own work and to evaluate their own performance. Of course, evaluation requires the guidance of the teacher who has access to many sources and who can gather all data for tests. He will be able to moderate or confirm the pupil's opinion of his own work.

If courses of the Intermediate Division are carefully designed to suit the students enrolled in them, there should be fewer occasions when a pupil's performance does not match his hopes—in short, where there is failure. When evaluation is used primarily as a means of determining promotion, however, the comment of one Ontario student that "you cannot have a course with a spirit of adventure and discovery while the god of marks is continually looking over your shoulder" becomes a valid criticism.

Creativity

A science program should be rich in opportunities for the development of the student's creative abilities. Many scientists spend their lives inquiring into the nature of the universe. Children, too, should make their inquiries. Any discovery method that is adequately planned and that provides carefully interpreted data gives the student opportunities to develop his resourcefulness, his imagination, his technical inventiveness, and his theoretical reasoning ability.

There is a place for open-ended inquiry as well as directed inquiry. Children must have opportunities to ask their own questions, to devise their own methods of investigation, to express their findings in their own way, and to draw their own conclusions. Because too few classrooms in the past have been places for open inquiry, these creative methods deserve special encouragement.

Joy and Satisfaction

Alfred North Whitehead has said that science is "almost wholly the outgrowth of pleasurable intellectual curiosity." Robert S. Morrison of Cornell University has expressed a concern that "few students seem to have very much fun either in their science courses specifically or in university life in general." In science programs students should find the exhilaration that comes from gaining an understanding of previously mystifying events as a result of one's own experiments and the satisfaction that comes from a realization of increasing competence.

Coherence

A curriculum should have unity resulting from a coherent structure and continuity. Scraps of knowledge have nothing to do with education. There must be some sort of structure in the planning and in the development of the program. Any unifying influence need not be totally consistent across the province, nor even throughout a local jurisdiction. The curricular framework, however, must be clear to each teacher and logical to the boys and girls.

[7] J.A. Comenius, *John Amos Comenius, 1592–1670, Selections*. Intro. Jean Piaget. (Paris: UNESCO; Ottawa: Queen's Printer, 1957), p.88.

Aesthetic Satisfaction

Feeling has its place in science, for science is always a personal attempt to understand the environment. In fact, science is more than contact with precise processes and impersonal technology; it involves people through their emotions.

Programs should allow for aesthetic experiences. In school, students can meet the physical beauty of colour, form, and shape in the natural world of crystals, clouds, and petals. Beauty can be found in an airfoil, in a sail, or the design of a microscope. Some will find beauty in a resonant circuit, others in the bright reflections produced by a curved mirror in sunlight. On field trips the serene solitude of moonlight on snow or the call of the loon can bring an empathy with nature.

Diversity

Only a small fraction of even the most basic scientific knowledge can be included in the school program and only a limited number of experiences can be provided in four years. The curriculum planner is responsible for ensuring that the student encounters important ideas and that he appreciates the wide range of ideas encompassed by the sciences. Unless a student has the opportunity to come into contact with such diverse phenomena as sandstone, parabolic mirrors, telescopes, back-swimmers, snowstorms, and spring floods, he is missing the diversity of science.

Unless they are diverse, new courses will only perpetuate the current pattern of specialized courses in high school, described by Leopold Klopfer as a "pale reflection of the traditional organization of science for the purpose of research, and of the departmental fragmentation established in colleges and universities for the purpose of training scientists in specific fields."[8] All categories of knowledge should be taught and studied as interdependent, each with its own contribution to the web of insight, knowledge, and experience of youth.

The objectives of science programs may be defined in general terms, indicating anticipated results in student development and understanding which defy accurate measurement, or in precisely defined performance capabilities with satisfactory levels of achievement clearly stated and examined. Both types of statements are to be found in the numerous science program projects available from commercial sources. It will be to the advantage of both the teacher and the students if the teacher is familiar with the techniques involved in describing segments of the program in terms of behavioural objectives. Reference works related to this approach to program planning will be found in the bibliography, but it should be remembered that not all planning, as indeed not all human behaviour, is subject to such techniques.

Objectives may also be regarded as criteria against which the merit of the program may be assessed subjectively as well as objectively. On the following pages, reference is made to only a limited number of such criteria in the context of a science program.

1. Are the concepts being developed in a context that makes them relevant to the student?

2. Are students given adequate opportunities to plan the procedures in an investigation themselves, to divide the study of the effects of different variables among themselves, so that they gain experience through assuming responsibility and encountering difficulties when responsibilities are not fulfilled?

3. Are the principles studied being applied to a variety of phenomena so that the student may gain an appreciation of their significance and hence attain a useful scientific literacy?

4. Are the students given ample opportunity to apply basic intellectual processes to the solving of a problem, to gain a realization of the processes that they have used, and to develop skill in this procedure through further application to investigations of their own selection?

5. Are the students given every opportunity to learn through personal handling of laboratory equipment and performance of experiments so that they may learn by doing and at the same time gain a respect for technical competence?

6. Are there periods of time, either short or long, when emphasis is given to studying a topic from all points of view that come to the students' minds so that the contributions of scientific knowledge are seen in the perspective of a broader integrated study?

7. Are the students encouraged to assess their own work frequently, to note their strengths, to analyse their weaknesses, and to plan a constructive program, in short, to develop a habit of self-evaluation?

8. Are students given the freedom required to foster development of their creative abilities?

9. Are areas of study approached in such a manner that the student finds excitement in learning and personal fulfilment in mastering a reasonable challenge?

10. Are investigations contributing to the development of understanding within a course outline that the teacher has analysed carefully and that the students have assisted in planning?

11. Are opportunities seized to enjoy the success of a well-performed experiment, to admire the beauty of form and colour observed in nature or in test tube content, to enjoy the aesthetic appreciation of a well-reasoned argument?

12. Are the science programs for the four years of the Intermediate Division planned to cover such a diversity of science studies that the students are given a reasonable view of the scope and the nature of scientific inquiries?

In planning the science program, teachers must be conscious that the study of science in any one year does not exist in isolation, but in a two-way continuum. The science course is part of the student's general education for that year, and it is also a part of his total formal education in science over a period of twelve years or more.

[8] Leopold E. Klopfer, "Integrated Science for the Secondary School: Process, Progress, and Prospects", *The Science Teacher* (November 1966), p.27.

The evolution of a program is a never-ending process that finds its ultimate realization in the interaction of student and teacher. Nevertheless there are many sources of information and stimulation available to the teacher. The various literature sources, a number of which are listed in the bibliography, the conferences of professional associations, various in-service professional development programs, and the discussions conducted by local curriculum committees all contribute to deepening the teacher's insight and expanding his scope of consideration.

In this publication, the teacher's attention is directed to only two areas of concern that influence the nature of the program. The first area is the psychological development of the child; the second is the choice in the organizational framework within which courses of study may be developed.

Since the time of Rousseau educators have recognized the value of using knowledge of child development as a basis for program planning. In the present day, such leading research workers in the field of learning theory as Piaget, Bruner, and Ausubel have done much to assist educators in understanding the psychological development of children, so that program planning and pedagogical techniques may be more effectively designed to achieve the defined educational objectives.

In his *Developmental Theory of Learning*[9] Piaget expresses his belief that a child's intellectual development progresses through four distinct stages. Although the age at which children reach a given stage of development will vary with individuals and with societies, the sequence of stages does not vary. They are as follows:

1. Sensory-Motor Stage
2. Pre-operational Stage
3. Stage of Concrete Operations
4. Stage of Formal Operations

Children in the Intermediate Division will probably be at the stage of concrete operations or the stage of formal operations. Those at the concrete operations level solve problems and develop explanations in terms of the concrete data available to them, but are not yet capable of forming hypothetical generalizations. The children who have attained the formal operations stage, however, are able to think in terms of abstractions. They can apply the knowledge gained from experiments to hypothetical cases and predict what will happen. When it is realized that children reach these levels of intellectual ability at different ages, it becomes apparent that the teacher of an Intermediate Division class must make it possible for students to study topics at different levels of understanding and must use approaches that give ample opportunity to work with students individually and in small groups.

Piaget has found that four factors contribute to the intellectual development of a child: maturation of his nervous system, his experience, social transmission, and equilibration or self-regulation. Piaget views the first three factors as passive, in that something is being done to the child. In relation to the fourth factor, the child is the active person, co-ordinating his own development during the process of self-regulation. This process is of the greatest importance, as it is during this process that the child begins to see the world as coherent and structured.

As far as education is concerned, one of the chief outcomes of this theory of intellectual development is a plea that children be allowed to do their own learning. Piaget's work does not indicate that intellectual development proceeds at its own pace regardless of what schools try to do; what it does indicate is that what schools often try to do may be ineffectual. You cannot further understanding in a child by simply talking to him. Good pedagogy must involve presenting the child with situations in which he himself experiments in the broadest sense of the term: trying things out to see what happens, manipulating things, manipulating symbols, posing questions and seeking his own answers, reconciling what he finds at one time with what he finds at another, and comparing his findings with those of other children.

It may be inferred from Piaget's studies that if children are allowed to do their own learning they will gain the ability to do new things, not simply repeat what others have done. This achievement may be regarded as a principal goal of education. Another related goal is the development of minds which do not accept everything as it is given, minds which can be critical and can verify. Slogans, collective opinions, and ready-made trends of thought are a present-day danger. Students must develop the ability to resist individually, to criticize, to distinguish between what is proven and what is not. Students must learn early to find out for themselves, partly by their spontaneous activity and partly through material set up for them. They must learn to distinguish what is verifiable and what is simply conjecture.

[9]Jean Piaget. "Development and Learning", *Journal of Research in Science Teaching*, vol. 3, no. 3, (1964). Reprinted in *Readings in Science Education for the Elementary School*, eds. E. Victor and M.S. Lerner. (New York: Macmillan Co.; Toronto: Collier-Macmillan Canada, Ltd., 1967) pp.321–34.

Bruner generally accepts Piaget's theory of intellectual development, but emphasizes the value of providing the growing child with problems that require him to reach forward to the next stage of development. Bruner is widely recognized as a strong proponent of discovery methods of learning. He has indicated that this approach to learning helps the student to develop his intellectual abilities, to shift from extrinsic to intrinsic rewards for his effort, to learn the heuristics of discovery, and to develop his memory processes.

Bruner emphasizes the importance of teaching a given topic or skill within the context of a broader, more fundamental structure of knowledge. If this approach is not taken, the student will gain little in intellectual excitement from his learning experience and will find it extremely difficult to apply his knowledge to new situations later. A student enjoys learning when he can see the usefulness of his learning in a variety of contexts. Furthermore, if knowledge is to be retained, it must be sufficiently organized to make the unifying relationship apparent.

Not all educational psychologists agree with Bruner on the importance of discovery methods, although some English schools have been using a heuristic approach since 1884. Ausubel, for example, argues that the discovery approach as a primary method of presenting subject matter is too time-consuming and inefficient. Another difficulty in using the discovery approach arises from children's subjectivity and their tendency to consider only one phase of the problem at a time. Ausubel argues for breadth over depth in the content of elementary school science, allowing for the occasional introduction of more detailed study to give the student a taste of scholarship and of research inquiry.

A knowledge of the findings of educational psychologists will obviously have a significant effect on the nature of the program planned. The annotated bibliography provides guidance to several sources of information in this area.

The intellectual development of the child is, of course, only one aspect of his growth. The Intermediate Division child is entering adolescence, a period of startling physical change accompanied by contrasting, unpredictable, and sometimes violent emotional behaviour.

Research indicates that most of our fears or angers are acquired ways of responding to various stimuli or situations, as are most of our other emotional patterns.

Documented studies show that such factors as health, physical growth, intelligence, and environment influence emotional development. "Since all aspects of growth are interrelated, the child's emotional growth affects and is affected by his physical, mental, and social growth."[10]

The intermediate school years (early adolescence) can be a time of "crushes", day-dreaming, impulsiveness, moodiness, instability, sensitivity, worry, insecurity, and fear. "The growth and development of the child into adolescence are accompanied by glandular changes closely related to emotional life. The heightened emotional states during this period of life have constantly been recognized as part of the nature of adolescents; however, in addition to the heightened emotional state at this time, there is also an expansion of the emotions into the social realm. Fears and angers related to social situations become very important; self-conscious feelings about one's adequacy appear; and the adolescent becomes especially concerned over the approval of his peers. This increased fear is also observed in connection with classroom situations. Fear of reciting in class, fear of failure, and fear of ridicule become more pronounced at this age level."[11]

At the same time the child has a high sensitivity to aesthetic stimulation. He is frequently noted to have a strong sense of duty and of right and wrong.

With today's emphasis on the development of the total personality, it would seem that as much attention should be given to the wide individual differences in emotional reactions as to those in physical and intellectual development. The teacher will find many opportunities to assist his students with this aspect of their development if the learning environment in the classroom is developed in accordance with the theories of Piaget as described earlier.

[10]Karl C. Garrison. *Psychology of Adolescence*, 6th ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc. 1964 (Toronto: Prentice-Hall of Canada Ltd.), p.107.

[11]Ibid., p. 122–23

The Intermediate Division is also a period of social readjustment. The curious, spontaneous, creative child of earlier years often becomes moody as he seeks to make sense out of his life. The energy level so high in the early years is no longer dependable and fluctuates greatly.

An awareness of the fallibility of adults takes on new importance and the peer culture starts to challenge adult influence. The children want responsibility, but they are not quite ready to assume it completely. The gloss wears off school for many children and the interests of boys and girls diverge.

Individual differences become clear during this period as character develops. Wide discrepancies in ability and interest appear with the ensuing succession of friends and social circles. Early in this period, boys gravitate towards gangs and clubs, while girls prefer to cling to a few good friends. As the girls, and later the boys, become aware of the opposite sex, a social changeover takes place and students want opportunities for mixed group activities. Often, however, much teasing and antagonism occur between the sexes before a good relationship is formed.

The teacher, aware of these changes, can meet the needs of the children without nagging, scolding, or talking down. Varied programs must be set up to meet the wide

range of maturity; group activities should be based on boys' and girls' interests. Understanding and a sense of humour are required from adults during this difficult period.

These children are interested in team games, outdoor activities, pets, hobbies, collections, radio, TV, comics, movies, and activities that will earn them money. They need opportunities for greater independence and for carrying more responsibility without pressure. They also need organized group activities such as weiner roasts, hikes, skating parties, and dancing, as well as opportunities to learn individual skills such as tennis, swimming, target games, music, and painting. Children of this age are becoming interested in preparing for a vocation and are ready to prepare for the future.

All of this adds up to one thing: the teacher must recognize that individual differences exist and he must adapt his teaching methods accordingly. More independent study, more diversity in classroom experiences, more project work, more small group activity must replace formal lessons in which the basic assumption is that all of the children in a particular classroom are capable of learning the material at hand and that they can learn it at the same rate. Every teacher should talk to his students individually as often as possible.

In science the student is seeking patterns that will make the universe appear reasonable. Within the structure of the science program each student is looking for *his own patterns*, and he selects the elements of structure that *he* needs.

Fortunately he doesn't need to do this alone for he can converse with his peers, seek answers from books and television, and look for guidance from his teachers. The student lives in a world that adults have already organized.

Unless a course of study and its supporting resources are consistent with each other, the student may often be frustrated in his efforts. It is the teacher's responsibility to provide the framework within which the student can work. Granted that students need the guidance that a structure gives, what can provide structure? There are several possibilities.

a) The Disciplines

Courses can be based on the several disciplines, such as biology, chemistry, geology, and physics. Traditionally the disciplines have provided the detailed structure. The study of animals, for instance, has generally followed the phylogenetic order: amoeba, crayfish, insects, fish, frog, bird, man.

The order in which topics are treated in the disciplines has largely been a matter of convention; the scope and sequence of science courses can be linked closely to these disciplines.

b) Conceptual Schemes

The current knowledge explosion has forced people to recognize what they in fact had been doing for many years: abandoning the hope of learning all the facts or even all the immediately relevant facts in any given situation. Hence teachers have sought new patterns of organization of knowledge which would facilitate the learning processes. One such pattern is based on the grouping of facts that contribute to the development of a generalization or concept. Similarly, concepts can be joined to other concepts in a framework called a conceptual scheme, which is a much broader generalization than an individual concept. Thus a structure can be devised which can stockpile a great deal of information for use, which can show relationships between ideas, and which can receive concepts that come with new knowledge.

An example of the hierarchy of concepts based on their sophistication and their specificity might start with the idea of *rivers* (as opposed to a particular river). This is a low order of specific concept. A high order would be the broad, more general concepts of gravity and the fluidity of water. Still higher would be the idea that there are fundamental universal forces of which gravity is one. These concepts could in turn be considered as factors contributing to the conceptual scheme that *all interacting units of matter tend towards equilibrium states in which the energy content is a minimum.*

It should be pointed out that every teacher has his own conceptual schemes which he uses in his teaching, and every pupil develops his conceptual schemes no matter how he is taught. An education that stresses the *great ideas* rather than trivial scraps of information, however, will bring the student into contact with science that has *survival value.*

c) Domains

Wherever a domain can be identified, a course can be devised. *Space and Man* is an example of a course based on a domain. Space as a domain extends from the earth's atmosphere outwards to the farthest galaxies, and all that is found within that domain is potentially part of the course. A domain may, however, be as local as the *schoolyard* or as international as *forests*. The identifying characteristic of the domain-based course is that it involves the study of all aspects of interests of a given topic.

There is a distinction between a course founded on a domain and one founded on a discipline. A domain-based course on *lakes and streams* would be more comprehensive than a course in *limnology*, a subject with a conventional pattern; the former study would range far beyond the confines of science, even though it stayed within its domain. The strength of domain-centred courses lies in the opportunity to integrate knowledge from many traditional disciplines, thereby giving the student a richer educational experience than he would gain otherwise.

d) Themes

Themes might provide the element of structure for a month, a semester, or a year. *What is a Scientist? The Abatement of Air Pollution, Growth and Development* are examples of themes which, for some students, give the knowledge gained during the study a much greater relevance than is developed through a subject discipline organization. Information from many fields of science and other areas may be called upon in the study of a theme.

The thematic approach brings together factual information and underlying concepts in a unique relationship as the study of the theme threads its way across traditional boundaries of organizational patterns.

e) The Processes of Science

The intellectual skills characteristic of the scientific enterprise offer a basis for program organization. Observing, classifying, recording data, communicating, predicting, inferring, hypothesizing, formulating models are some of the identifiable modes of scientific thinking, and each in itself could become part of the core program. Content could be chosen from the various disciplines on the basis of how well it contributes toward developing in students familiarity with the process being considered.

Whatever the unifying framework, once it is chosen it would be in order to designate a core of basic concepts to be dealt with and to arrange that each student have the opportunity to select topics extending from and related to the core. The time allotted to either the core or to the extension of it would be determined by both teacher and student on the basis of a student's needs, ability, and interests.

For example, in developing the theme "how machines aid man", the teacher might plan for experimental work on the six types of machines, and, after studying levers, inclined planes, and so forth, a large block of time could be set aside to examine children's toys, road vehicles, kitchen gadgets, and carpenters' tools. Possibly half the time could be allocated to the extensive work of the students and half reserved for the core segment.

Students should be made aware of the processes of science by having them consciously and carefully incorporated into their daily experiences in such a way that both process and content develop concurrently. To develop content without developing the processes by which it is attained would deprive students of a rich contributory area of science education. The intellectual skills associated with science and the positive attitudes that they encourage may be profitably drawn upon when a student is engaged in other studies, for these skills direct a student's reasoning in any area of endeavour.

Since skills are mastered through practice, a dominant characteristic of the science program should be purposeful activity in which the student exercises the methods of processing information. Extensions of a core could well be regarded as inquiry situations in which a student is given opportunity to employ these skills. A worthy learning situation can develop when a student is encouraged to pursue his inquiry to the point of creating a model to explain the phenomena under study and to serve as the basis for predicting phenomena that are new to him. Formulating models, whether they be physical, mental, or mathematical, is a creative, imaginative skill which is inextricable from the scientific enterprise. Models are pivotal points in our progress, serving both to explain and to predict phenomenom of nature. Seeking and modifying models is intrinsic to science. Indeed, to have our students appreciate science as a human, self-correcting, ongoing activity, is to have them experience this process.

Any master plan must provide schools with a sense of direction, yet it must leave room for a wide measure of choice. These aspects of planning contradict each other but each is essential. One compromise is a broad plan devised on the county-wide, district or municipal basis and an operating plan devised by the teacher in a classroom in consultation with the students.

a) The County or District Plan

A central group, consisting of teachers experienced in teaching science to the younger Intermediate Division children and others experienced in teaching science to the more senior Intermediate Division children, could be organized to prepare recommendations for a local science program. Local supervisory officers and the program consultant in science from the Department of Education could serve in leadership, advisory or consultative capacities. A group might include representatives of both the public and separate school systems.

This planning group could prepare a statement of objectives for the science program in the Intermediate Division. A summary of current theories of learning could also be prepared with examples to illustrate the possible influence of these theories on the organization and techniques of presentation of the program. The committee could outline the major areas of study for each of the four years of the Intermediate Division, providing useful suggestions concerning the development of subject material to be studied, processes of learning and investigation to be emphasized, and the attitudes to be fostered.

Thus one educational jurisdiction might base its science program on a plan in which the first year is devoted to the study of physical sciences, the second to the biological sciences, the third to the earth sciences, and the fourth to a return to physical sciences on a more advanced level. Another educational authority might follow a semester plan that allows students to take one or more semesters of science each term according to a suggested sequence of areas of study. The county or district authority might, however, consider that the foregoing examples are too prescriptive and suggest that decisions on science programs be made at a level closer to the student. In this case more general goals could be set down by the county or district group, goals that are a part of all education.

Although the master plan for the Intermediate Science program may vary considerably from one jurisdiction to another, it is expected that all plans would provide the student with a variety of experiences in several fields of science, and at the same time give emphasis to basic scientific principles arising from the study of biology, chemistry, and physics. If the students are offered alternative areas of study in science, the sequence of selections should be arranged so that these expectations will be realized.

b) The Family-of-schools Plan

A further step in the process of curriculum development could take place at the family-of-schools level. A family of schools consists of a secondary school and the elementary schools that normally provide it with students. The teachers of science from such a group of schools could meet to discuss how their *family* might develop its program within the broad master plan developed on a county or district basis. The teachers would take inventory of the resources of personnel, equipment, and environment available to them and from these considerations determine in more detail the possible approaches that could be taken to implement the master plan.

As an example of the preliminary expansion of a theme which the family-of-schools might produce, a brief outline of three possible approaches to the study of *Growth and Development* follows:

The core and extension approach is frequently used in conjunction with a subject discipline-based course of study. The teachers must decide what portion of the topic to be studied is essential to give the pupils an understanding of the fundamental ideas and processes involved in the study and what portion could be considered as valuable for expanding this understanding and for providing openings to more advanced investigations. If the study of *Growth and Development* were to start during the first year of the Intermediate Division, the following outline might be considered appropriate for the core studies, in view of the background experience of the students in this aspect of scientific studies.

- examination of bean seeds to identify their parts
- planting the seeds
- observation of evidence of seed germination and growth
- measuring the rate of growth of the plants.

Studies that would extend the student's knowledge and lead to further inquiries might include:

- examination and planting of the seeds of other plants to determine some of the differences between monocotyledons and dicotyledons
- chemical testing of different sections of the seeds of monocotyledons and dicotyledons for the presence of starch
- experiments to determine the conditions required for the germination of the seeds

- experiments to determine the relative rates of germination of the seeds of different plants and the percentage of the seeds of each species which germinate
- experiments to determine the effect of various variables on the rate of growth of plants.

The necessity of using control tests to obtain meaningful experimental data would become evident as preliminary test results were examined.

The family-of-schools might also illustrate the presentation of the topic *Growth and Development* within the framework of a conceptual scheme approach. In this organization, a broad generalization is used to provide a framework from which many related concepts may be developed. Growth and development are common to all living organisms and, under different criteria, to many non-living things such as glaciers, mountains, and rivers. Concepts developed within these two areas may be related to concepts developed in other areas of study as components of the conceptual scheme *All Things are in Constant Change*. For example, the study of seeds and plant growth could form part of the sequence of concepts developed from an investigation of the growth and development of living organisms.

The following chart represents a possible concept sequence in this area:

Conceptual scheme:
All things are in constant change

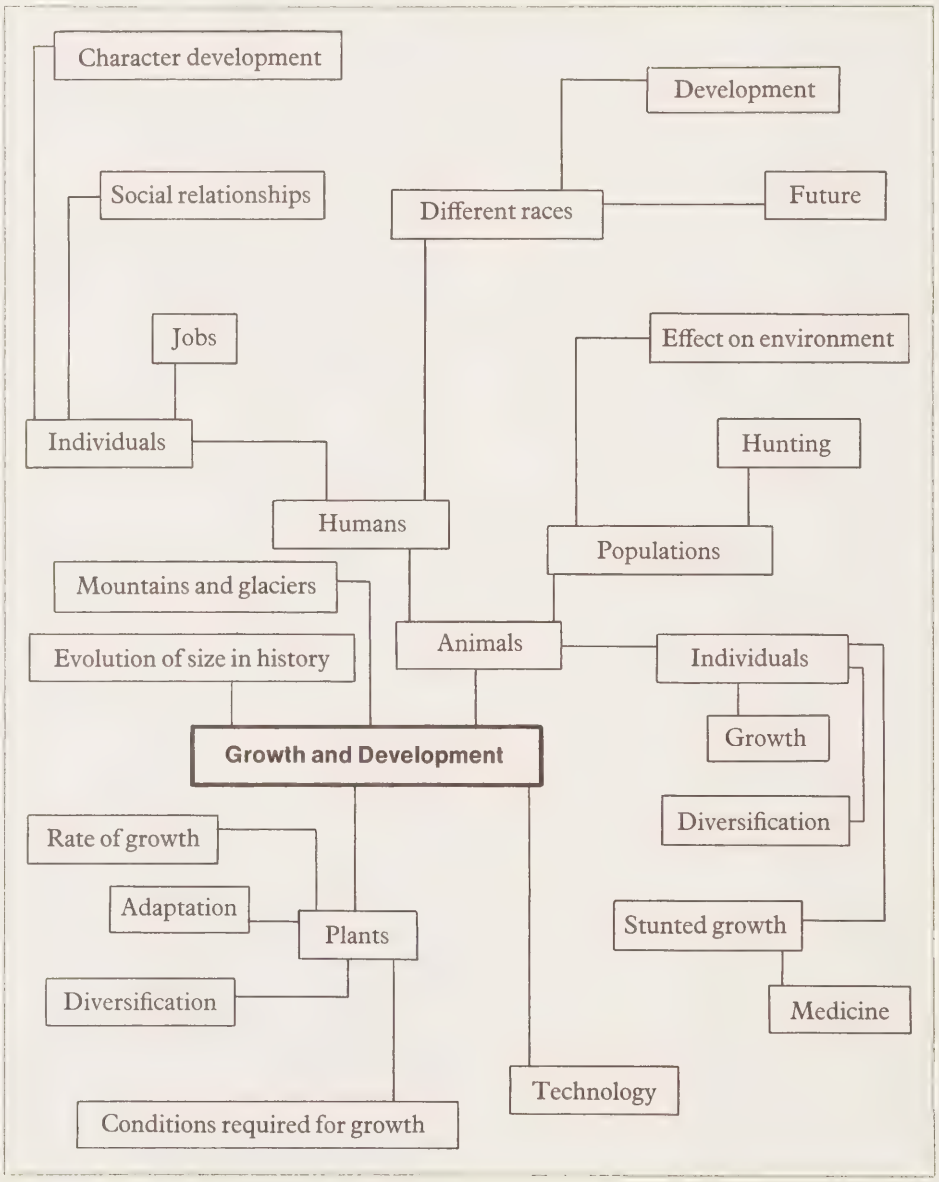
Concept
Growth at a cellular and organism level causes changes.
Example
—development of plant seeds and fertilized animal eggs

Concept
The ability to adapt makes survival possible.
Example
—plant and animal adaptation to various environments

Concept
Inability to change can result in species extinction.
Example
—extinction of dinosaurs

Concept
Ecosystems evolve through ecological succession.
Example
—change in flora and fauna associated with a change in environment, as exemplified by the sand dune to forest succession or the spruce bog succession

Growth and Development could also be used as a unifying theme to provide the stimulus for a wide-ranging interdisciplinary study. The following dendritic diagram illustrates a possible development of this theme and indicates that once again even the study of seeds and plant growth may evolve naturally from the sequence of topics.



In conclusion it is evident that the family-of-schools can provide a valuable resource service to the individual teachers within the *family*. As a result of the combined efforts of a number of people of diverse backgrounds, a variety of approaches to major areas of study can be outlined, thereby providing the schools with a preview of some of the relationships and insights that students might gain.

c) The School Plan

The final step in the program development sequence, and also the most significant step, takes place in the individual school. Here each teacher, through discussions with his students and other staff members, determines what science experiences students will undertake. In all probability a great diversity of approaches are utilized throughout the schools of a given educational jurisdiction. While one teacher might guide and assist his students to recognize and understand basic objectives through a series of student-determined investigations, another teacher might choose to organize a more traditional sequence of laboratory exercises in order to develop essential skills and concepts and then allow students to practise their skills in investigations that they select in conjunction with the teacher. In one school the various science disciplines may be clearly identifiable from year to year, while in another an integrated-studies approach encompassing three or four traditional subject areas may be in effect for a semester or at periodic intervals.

The teacher may find that the realization of short- and long-term objectives sought in the study of any topic will be enhanced if time is allotted before the study is undertaken, to express these objectives as clearly as possible, and to design evaluation techniques to assess the extent to which these objectives are realized.

The following examples are intended to give an indication of the wide variety of areas of investigation which might be recommended by a county or district planning committee and the great diversity of science discipline interrelationships which individual teachers might consider. It is anticipated that the family-of-schools suggestions for alternative course structures will be of unique value to the teacher in further developing the courses of study with his classes. The examples are neither prescriptive nor exhaustive.

Ecology

Through the exploration of their natural environment students come to realize that all ecosystems (forests, ponds, meadows, lakes) have three basic biological components: producers, consumers, and decomposers. Studies in the field and laboratory of the roles of these components introduce students to many basic biological concepts and lead naturally to interdisciplinary studies. For example, a study of the role of producers introduces the concept of photosynthesis; a study of the roles of consumers and decomposers introduces respiration and other physiological processes; a study of how the three basic biological components interact to form the biotic portion of an ecosystem leads into the field of chemistry. An investigation of nutrient cycles such as the carbon, nitrogen, and phosphorus cycles are further examples of related studies.

Field trips afford opportunities to utilize concepts from various subject areas. Physics concepts are used as students measure temperature, light penetration, stream velocity, and wind velocity; mathematical skills are used as students determine stream profiles, incline of the land, and particle size of the soil; geographical skills are used as students map the study site or the course of a stream.

Air

The study of air offers a multitude of avenues for investigation. Experiments designed to provide evidence that air has mass and exerts pressure may lead to quantitative measures of these properties including the construction of barometers. The significance of air pressure in such ordinary applications as drinking straws and suction cups may lead to an investigation of pressure differences associated with moving air columns and examples of Bernoulli's Principle. The effect of temperature on air density would lead naturally into a discussion of air currents in nature. A study of air pressure and composition may lead to studies concerning underwater exploration and space travel.

A more detailed study of the composition of air may serve as an introduction to chemistry. The chemical properties of the major gases found in air may be studied by preparing the gases in the laboratory or by using samples obtained from commercially available compressed cylinders. A study of oxides, acids, and bases is an obvious area for investigation. The presence of air pollutants might be measured and the resultant damage to both living and non-living matter examined.

The role of oxygen in life processes and the harmful effects of air pollutants on these processes provide yet another avenue of approach to a study of the biological sciences. The nitrogen and carbon cycles are also natural developments evolving from a study of air.

Geology

Space exploration and underwater exploration have both tended to increase interest in the geology of the planet earth. This field of study could be divided into three main sections: physical geology, historical geology, and the geology of the area surrounding the school.

Physical geology is concerned with the crust of the earth and processes that lead to its formation and change. If local rocks and minerals are available, the collection and identification of good specimens may be assigned as a project early in the autumn. Ideally, a class set of the main rock-forming minerals and of common rocks should be available for reference purposes. The study of the earth's crust also calls for the use of topographic and geologic models.

Historical geology surveys the origin of the earth, the evolution of life, and the study of fossils and their interpretation in geologic history. The geologic timetable could be presented to illustrate the history of the planet in terms of eras, periods, and epochs, including characteristics of life and physical events related to these specific times.

The interpretation of the local geology in terms of the factors mentioned above would be an integral part of this study. The topography should be understood in terms of its crustal history, surface glaciation, and subsequent erosion. Local fossils could be related to the geologic timetable and the ages of bedrock and outcroppings could be determined.

The Molecular Theory of Matter

An effective approach to this theme might consist of an intensive experimental study of the bulk properties of matter. This study should concentrate on macroscopic *physical* properties of the three states of matter. Investigations would include a study of such phenomena as changes of state; density of solids, liquids, and gases; effects of temperature and pressure changes on the three states of matter. These experiments provide the students with the concrete experiences they require before they can proceed to the abstract stage of formulating a theory to explain the physical behaviour of matter.

At one extreme, the experiments could be spread over the four years of the Intermediate Division. At the other extreme, they could all be performed in one year as part of a full year physical science course. In either case, the objective would be the same: to give students opportunities to observe matter and allow them to develop a theory to explain their observations. This theory could then be used in more advanced scientific tasks such as the prediction of the results of future experiments and the explanation of natural phenomena encountered by students.

Atomic Theory

A study of atomic theory would follow naturally from a study of the molecular nature of matter. Moreover, because of its abstract nature, it is best to leave study of the topic until the latter half of the Intermediate Division.

Experiments on the conservation of mass and constant composition may give students sufficient empirical background to attempt an explanation of the *chemical* behaviour of matter. The end result could be the establishment of a simple atomic model, the Dalton model. This model can be used to predict such phenomena as multiple proportions and should motivate experiments that test predictions. These will increase the students' confidence in the predictive value of models and theories. Phenomena such as radioactivity and emission spectra could then be studied briefly to show the students that their model has limitations.

From this study students will learn that scientific models evolve continually and that they have limits beyond which they cannot be used. This appreciation will grow as subsequent studies in the Senior Division result in more complex atomic models.

Astronomy

Astronomy can be studied at any level in the Intermediate Division. It is of intrinsic interest to people of all ages and the wealth of materials available in the area makes it easy for the teacher to accommodate the interests and abilities of the students. For those students who proceed to study mathematics and physics at more advanced levels, an introduction to astronomy will provide a useful background.

The widely publicized space flights provide a natural starting point for studies of astronomy as do the less publicized launchings of satellites.

On the other hand, a systematic study of astronomy might commence with a discussion of the various theories of the origin of the universe followed by an investigation of successively smaller components of the universe—galaxies, star clusters, nebulae, star systems, solar systems, stars, planets, and satellites. An in-depth study of a particular star, the sun, could be undertaken by interested students. Their investigations might include the use of a small telescope to view sunspot reflections on successive days and to plot their rotation.

Another approach would be to begin with a study of the earth and to move successively outward, terminating with a study of the theories of the origin of the universe. A study of the seasonal changes of the earth, its ice caps and retentive atmosphere would undoubtedly give rise to a study of other planets and an assessment of the probability that another planet also supports living organisms as we know them. Consideration of the rotation of the planets around the sun should give rise to a discussion of the origin of the solar system. A good six-inch reflecting telescope or a three-inch refracting telescope would be of great assistance in evening laboratory sessions devoted to studying the features of the moon and relating these to data obtained as a result of the Apollo lunar landings. Good binoculars are another valuable laboratory instrument.

Meteors and meteor showers can be observed, and meteor counts could be taken and their frequencies and positions plotted on a star map to determine their possible origins. The information gained from the analysis of meteorites can be a topic for student research.

From time to time comets may be sighted by the naked eye, binoculars, or small telescopes. These glimpses, if they should be possible, will stimulate interest in the return of Halley's Comet in 1986.

Biological Sciences

Biological sciences form an imperative part of any child's education not only because of the information that it provides about his own body structure and processes but also because of the greater understanding and appreciation that it provides of all living forms in his world.

The microscopic examination of plant and animal cells involving the preparation of slides and simple staining techniques may lead to a study of fundamental cell processes such as diffusion, osmosis, assimilation, excretion, respiration, mitosis, and meiosis. A consideration of the concept of life and a brief introduction to the role of the DNA molecule might be used as background for the study of the division of the cell nucleus and later studies on heredity. The multiplication of cells leads to cell specialization and to consideration of more complex organisms.

In order that students might become familiar with the order and diversity exhibited by all forms of living organisms, two classical lines of investigation might be followed.

In the field of botany, a progressive series of investigations and observations would take the students up the evolutionary tree from the viruses, bacteria, fungi and algae through the lichens, mosses and ferns to the seed-bearing plants, the gymnosperms and angiosperms.

The evolutionary trends might be investigated by comparing the development of specific vascular and reproductive systems.

A parallel zoological investigation would start with the Protozoa and Coelenterata, through the Annelida and Arthropoda and on to each of the vertebrate classes, Pisces, Amphibia, Reptilia, Aves and Mammalia.

Teachers might be interested in examining the diversity of forms within the phyla. The phyla Protozoa, Arthropoda or the class Mammalia of the phylum Chordata are particularly suitable for this purpose.

It is essential that these two areas be seen in their natural relationship. After the proper background has been provided by individual studies of the plant and animal kingdoms, the two areas might be tied together again by the study of genetics, evolution, and ecology. Each of these areas accentuates the biological processes that are common to all living things and their relationships to one another.

The generous use of suitable microscope slides and both living and preserved plant and animal specimens will greatly enhance investigations of biological phenomena.

Wherever feasible, field trips should be taken to apply the concepts and skills learned.

A large selection of coloured slides, filmloops and films is available to supplement the students' own observations.

Thermal Energy

The study of energy in its various forms could provide the theme for a course of study designed to introduce the student to many aspects of biology, chemistry, and physics. A study of thermal energy as part of the wider theme encompasses many ideas, experiments, and applications suitable for students throughout the Intermediate Division.

Experiments that investigate the transmission of heat by conduction, convection, and radiation provide explanations for many common phenomena. The formulation of theories to explain heat transfer could lead to a discussion of the kinetic molecular theory of matter, which could be explored further by an experimental study of the changes of state. The application of this information to various weather conditions is a natural expansion.

As mathematical skills, including the solving of simple algebraic equations, are developed, students may be introduced to more accurate techniques of investigating heat transfer involving calorimetry.

Mechanics

The study of mechanics is basic to most branches of science. It would be desirable, therefore, to expose students to situations that might stimulate an interest in the study of such topics as motion, force, and energy. Examples of bodies in motion could be investigated and the motion described and measured. In all probability the cause of the motion will become of interest to the student and this should lead naturally into the study of forces.

Various objects may be subjected to the pushes and pulls of gravity, magnetism, electromagnetism, elasticity, buoyancy, friction, and objects with which they are in direct contact. The study may involve the vector nature of forces, their measurement, force analysis diagrams, effects of balanced and unbalanced forces, and properties of force fields.

Although detailed mathematical treatment is neither necessary nor appropriate, the measurement of mass, distance, and time will probably become an integral part of the study of motion and force. This may, as opportunities arise, lead to brief consideration of such related topics as the measurement of area, volume, density, and pressure. For example, if a solid immersed in a liquid experiences a buoyant force, the relative densities of the solid and liquid become important and the pressures exerted on the solid become factors in the explanation of the resultant hydrostatic phenomenon. It is strongly urged that the systeme International d'Unités (SI units) be introduced, but in an elementary fashion at this stage. For instance, the Newton force could be treated in terms of an arbitrary pull exerted by a spring balance and need not be derived from Newton's second law.

The study of forces can lead into mechanics where the joule could be introduced, followed by a study of transformations and conservation. The idea of power could round out the study of mechanics, with a consideration of the watt as the preferred unit of measuring the rate of energy transfer. It may be well to expand the topic of energy to look at heat and deal with such topics as heat capacity, heat transfer, and latent heat.

The fact that motion, force, and energy are basic and related concepts in other branches of physics and in chemistry, biology, geology, astronomy, meteorology, and many aspects of everyday life should be made evident to the students throughout their study of mechanics.

The Bicycle

Many aspects of a student's daily life provide a natural and relevant context within which objectives of the science program can be realized. This brief outline provides an example of this approach using a bicycle.

The bicycle can be a useful laboratory tool for developing fundamental principles and concepts in physics as well as for demonstrating technological applications of physics. The student's own bicycle illustrates the principles of measurement, levers, gear ratios, speed, acceleration, force, Newton's laws of motion, conservation of momentum, moments for forces, work and energy, power, pressure on surfaces and air pressure in closed containers, friction, and distribution of weight on the supports of a beam.

Other aspects of physics, and particularly technology, can be investigated through bicycle accessories such as horns, bells, electrical generators, head and tail lights, reflectors, mirrors, speedometers, odometers, and air pressure gauges. A study of the interaction of tires and the frictional forces of the road could lead to a study of road building materials; students could experiment to determine why some surfaces are more slippery than others. Other areas of interest include colour, rusting, and lubrication.

The bicycle provides an opportunity to examine principles of physics outside the school laboratory as well as inside, thus showing students that what they are learning has application to real life and is not just merely of academic interest.

All of the foregoing aspects, combined with the mathematical tools that must accompany them, make the bicycle a fascinating laboratory instrument.

Sound and Light

Acoustic and optical systems are becoming part of the everyday life of the general public. Elements of sound and light, therefore, are of vital interest to many students. If the study is attempted during the first two years of the Intermediate Division, some teachers may find it advisable to treat sound and light as two separate areas of study. Investigations at this level would be primarily designed to discover the properties of the phenomena with little or no attempt at theoretical explanation. If the study is undertaken at a later stage, teachers may wish to study the two areas simultaneously, as both are related to the transmission of energy by a wave motion.

As both sound and light are utilized in various audio-visual devices, an examination of how these devices operate might serve as an introduction to this study. Another approach might be to study properties of waves in ropes, slinkies, and ripple tanks, and then seek for similar properties in sound and light. Musical instruments may be used to examine many of the characteristics of sound, and simple ray boxes can assist greatly in the study of geometric optics. In all events, the student should have considerable practical work to make his investigations realistic.

The study of sound may include its transmission through various media, the speed at which it travels, and the reason it travels at all. This could lead into an elementary investigation of vibratory and wave phenomena. Characteristics of sound should also be of interest to students as they consider the ranges of intensity, frequency, and quality that are a part of their own experience. Additional topics for study include noise pollution, the sonic boom, ultrasonics, sounds audible to dogs, bats and porpoises, depth sounding, sonar, acoustic interference and reverberation in an auditorium, the tuning of strings by beat frequencies, sonic refraction, and seismic prospecting.

A historical approach to various explanations of light propagation might constitute a suitable introduction to the study of light. Characteristics of the transmission, reflection, and refraction of light can be studied from the viewpoint of geometric optics. For some students, the particle nature of light may become evident. Some very simple experiences involving interference and polarization could be introduced to show the wave nature of light. For further study, students might explore colour formation, spectrum analysis, the laser, measurement of luminous intensities, methods of determining the speed of light, and applications of polarized light. Students might also be interested in attempting an explanation of some particular optical device such as the microscope, telescope, projector, or camera.

Magnetism and Electricity

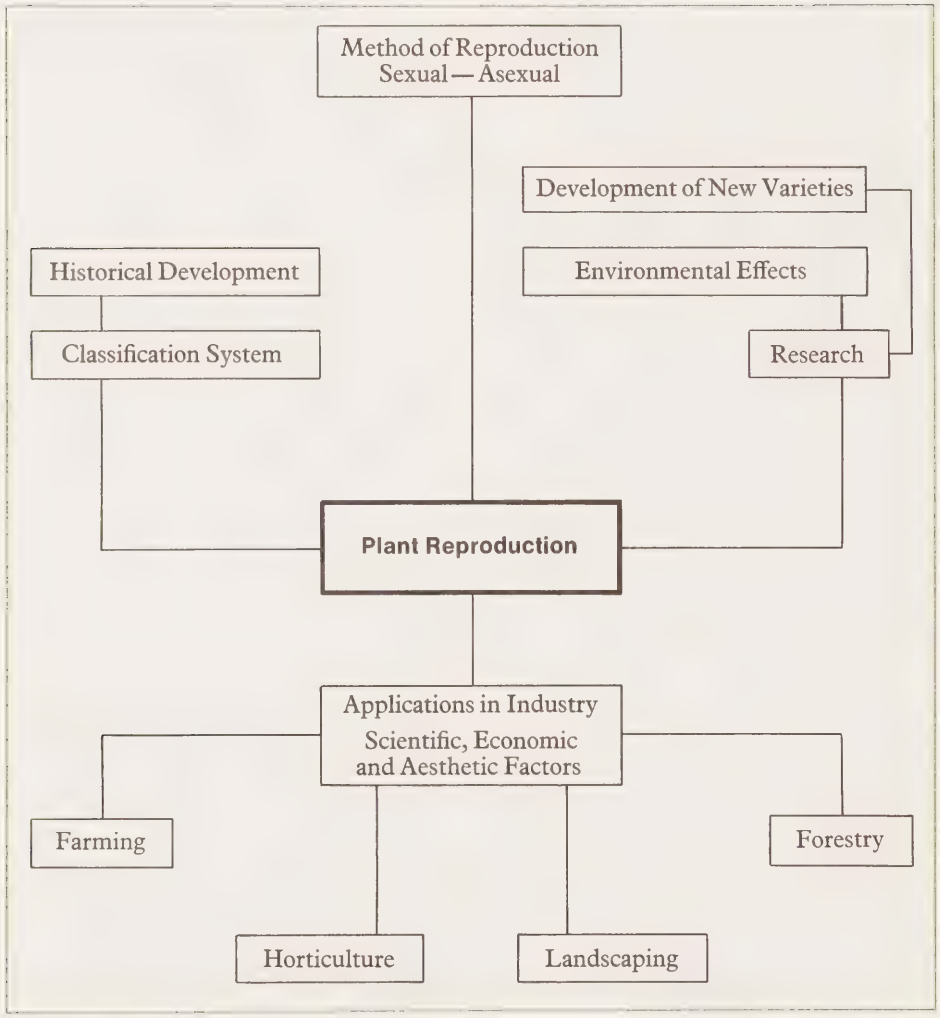
We are living in an electric age. It is therefore essential that the science student become familiar with some of the basic ideas involved in magnetism and electricity. Many students will have had considerable experience with simple apparatus and this practical background should be further expanded. Theory alone is insufficient.

Students might be encouraged to investigate the properties of the force field around magnets of different shape, the interaction between the force fields of pairs of magnets, and the interaction of the earth's field with that of a compass. Discussions could centre around theories of magnetism in terms of molecular dipoles or even ferromagnetic domains. Investigation and discussion will show students that magnetism can exert forces and transfer energy. Consideration of methods of producing magnetism, particularly electromagnetism, will naturally introduce the study of electricity. Students could conduct experiments to detect the magnetic field of an electric conductor or a helix. They could make simple electric meters to enhance their understanding of how a current may be detected or measured and how a potential difference may be indicated. Simple circuitry could enable students to determine how electric currents flow through various combinations of networks. Consideration could also be given to such electrical units as the ampere, volt, coulomb, joule, and watt. Students might gain an insight into some of the theories of electricity from a unit on electrostatics. Some time could be devoted to practical applications in which magnetism and electricity might be related to other forms of energy in the production of sound, light, heat, and motion.

For special projects or further study, students might consider such topics as electrolysis, electric motors, generators, lighting systems, domestic appliances, telegraphy, simple computers, and elementary electronics. Care should be exercised in maintaining such studies at a level appropriate for the individual student.

Plant Reproduction

The theme of plant reproduction can lead to a wide variety of areas of study depending upon the local environment, the students' interests and background and the teachers' objectives for the study. The following diagram is intended to illustrate some of the possible relationships that might be considered:



Although the development of investigations related to classification and to research may be familiar to many teachers, a study of the applications of plant reproduction related to industry may represent new extensions of this theme.

A study of plant reproduction in the context of the farming operation provides an excellent opportunity for interdisciplinary studies involving teachers with special interest in biology, economics, geography, geology, history and technology. For some classes, a study of the formation of the various types of soil over the geological areas may precede a detailed study of the soil structure of samples taken from the local area. Examination of soil samples taken from different sections of a soil profile might include such factors as porosity, water-holding capacity, organic and inorganic matter, major and trace elements, and living organisms.

A consideration of soil characteristics, climatic conditions, and economic factors provides a basis for the determination of land use. The research work conducted at experimental farms operated by departments of agriculture and by universities may be studied through publications and visits to the farms themselves. This study may lead in turn to the establishment of research or development projects on plant specialization at the school. An investigation of fertilizers, insecticides, and fungicides, their use, and abuse is a further extension in this field of inquiry.

Some students may wish to study plant reproduction as it is related to the history of the development of farming as an economic enterprise. This study may range from the days of the early settlers when the clearing of land was a major task to the development of the multi-faceted family farm with its variety of livestock, fowl, grain crops, and market gardening aspects to the huge, highly specialized farming industry of today. The influence which local, national and international economics exerted on this development and the concurrent technological advances in farm machinery, transportation techniques, and food storage facilities, provide additional means of broadening the students' perspective.

In some cases the study of plant reproduction may find its most natural

development within the context of a study of horticulture. The teacher may find that members of a local horticultural society would be valuable resource persons in this study. The effect of changes in various environmental factors on different species of flowers, shrubs, trees, vegetables and fruit is a basic area for experimentation. The school laboratory, the school grounds, a greenhouse, or the students' home gardens may all serve as experimental growing sites. The development of variations in a given species involves the study of genetics and sexual and asexual means of reproduction. The economic and aesthetic aspects of horticulture are also valuable areas of study.

The study of horticulture inevitably leads to a consideration of landscape gardening. The knowledge of the horticulturist finds expression in the artistic display of the landscape gardener. Some students may find that the planning and maintenance of garden areas on the school grounds provide the motivation that makes the study of basic scientific concepts a relevant learning experience. Others may find that this aspect of their science studies leads them to explore such areas as photography, art, or poetry.

In some areas of Ontario a study of plant growth may lead to a brief study of forestry. Once again a team of teachers may combine with local resource persons to assist students in investigating the numerous aspects of forestry: the tree as a plant with its specialized biochemical system and life history, the varieties of trees with their unique properties and related uses, the environmental factors influencing the ecology of the forest, the different ecosystems found in different types of woodlots, the management of forests as a commercial crop, the technological developments in the forest industry over a span of several decades and their influence on the economics of the industry, the continual changes in international trading patterns and the effect of this factor on the forest industry in Canada, and the use of forests as conservation areas, public parks, and campsites.

It is apparent from the brief outline given that a science based theme may provide the vehicle for the organization of an interdisciplinary study supported by teachers with a wide variety of special interests and backgrounds.

The Gravel Pit or Quarry

The study of a gravel pit or a quarry may be considered as an example of an inquiry project that is based on a feature of the local environment and which provides a rich opportunity for interdisciplinary studies. Teachers with special interest in the fields of biology, chemistry, geography, geology, lithology, mathematics, or technology may wish to act as a resource team for the students as well as serve as a planning team for the project.

The land formations of the area may be examined both by means of a field trip and the study of geological and physiographical maps. The study of the exposed soil profile at some gravel pit sites may lead to an examination of the soil properties and the formation of an hypothesis concerning the relationship between these properties and the nature of the vegetation in the area. The pit face may be examined for such features as the shapes and sizes of the rocks. As a sorting process will have taken place during the original formation of the pit, hypotheses may be formed concerning possible explanations for the shapes of the rocks and for the relative position of rocks of different sizes. The water table level may also be identifiable in some pits and the relationship of this feature to the structure of the region investigated.

Examination of rock samples at a quarry site by visual inspection and by simple tests such as scratching with a piece of double-diamond glass or chipping with a chisel and hammer may lead to suggestions for a variety of possible classification schemes and the introduction of an acceptable scheme. The properties of the rocks and their related uses may be investigated. Fossils may also be found which could lead to a search for further information on early forms of plant and animal life and the events that lead to their fossilization. A study of the various components that combine to form the rock samples may lead to an introduction of the chemical properties of the elements and elementary chemical analysis on the one hand or to a study of mining on the other.

The equipment used in the operation of a gravel pit will undoubtedly provide an exciting area of investigation for some students. If the equipment can be observed in operation, students can follow more readily the complete process from the removal of the raw material to the completion of the finished products. The relationship between the properties of the product and the use that is made of it provides another avenue for investigation.

The costs of production and the contribution of the gravel pit or quarry to the economy of the region are economic aspects worthy of investigation.

The ecosystem found in and around a gravel pit or quarry will offer a unique area of study. The particular type of plant life, the species of birds and their nesting habits, and the small animal life provide an interesting biological system. Pools of water frequently found in pits provide yet another biome.

A study of mathematical relationships may also form an interesting part of this project. Calculations may include such items as determining the relationship between the mass and volume of small rock samples of similar and of different appearance, the number of front-end loaders of earth required to remove the overburden from a deposit of gravel, the distance across the pit, and the depth of the pit.

When all the useful material has been removed from the pit or quarry, a study of the reclamation of the site may be made. The geographical and economic factors that govern the reclamation process in such a case can also be applied to a variety of other situations where the development of the environment to meet the needs of society must be considered.

Although some of the possible avenues of inquiry centred about a gravel pit or quarry have been indicated very briefly, it is apparent that environmental features offer abundant opportunities for unique and relevant interdisciplinary learning experiences.

Books marked with an asterisk are listed in the publication entitled *Circular 14, Textbooks*, 1971.

Books and periodicals marked with a maple leaf are Canadian.

Andersen, Hans O., ed. *Readings in Science Education for the Secondary School*. New York: Macmillan Co., 1969 (Galt, Ontario: Collier-Macmillan Canada, Ltd.).

This compendium of papers relates to teaching science in secondary schools. A wide variety of topics is included: means of studying science teaching, learning theory, ways of designing and evaluating science instruction, commentary on recently developed science curricula. In many instances the conflicting views of different educators have been given.

British Ministry of Education. *Science in Secondary Schools*. Pamphlet No. 38. Her Majesty's Stationery Office, 1960.

The report traces trends in science over the past century and proposes a new place for science.

Brown, Walter R. "Defining the Processes of Science". *The Science Teacher*, December 1968.

This publication describes certain processes of science, namely, application of generalizations to new situations, collection of data, analysis of data, synthesis of data, and evaluation of data.

Cohen, I. Bernard, and Watson, Fletcher G., eds. *General Education in Science*. Cambridge, Mass.: Harvard University Press, 1952 (Toronto: Saunders of Toronto Limited).

This anthology of papers on general education is concerned with college level programs. The volume contains statements of philosophic perspectives applicable to schooling at any level.

Connelly, F. Michael. "Enquiry Materials in Science Teaching". *The Crucible*. Article 1, January, 1970; Article 2, February-March, 1970; Article 3, April-May, 1970.

The first article in this series discusses the different uses of the word "enquiry".
The second article describes the six general characteristics of enquiry conceptions.
The third article describes a discussion method for a teaching-learning situation aimed at an understanding of enquiry as logic.

Dewey, John. "The Child and the Curriculum" in *The Child and the Curriculum: The School and Society*. Chicago: University of Chicago Press, 1956 (paperback).

The only direct essay on curriculum in which Dewey shows that the school reflects and reconstructs society.

Dewey, John. *Experience and Education*. New York: Collier Books, 1963 (Galt, Ontario: Collier-Macmillan Canada Ltd.; paperback).

This is one of Dewey's later statements on curriculum in which he tries to resolve the differences between "traditionalists" and "progressivists".

Dewey, John. "My Pedagogic Creed". *School Journal* LIV (1897), pp. 77–80.

One of Dewey's easiest writings to read, this excerpt presents his major philosophic position about the child, his curriculum, the school, society, subject matter, organization, and teachers.

Dubos, René. "Science and Man's Nature". *Daedalus* 94, no. 1 (1965).

In this article, Dubos coins the phrase "the anti-science movement". Dubos argues that man is modifying his environment so that it is in conflict with man's nature. He further argues that the content of scientific knowledge has little to do with ordinary experience.

Grobman, Hulda. *Evaluation Activities of Curriculum Projects*. Chicago: Rand McNally & Co., 1968 (Toronto: W. J. Gage Ltd.).

This is the second publication of the Monograph Series on Curriculum Evaluation, prepared under the direction of the American Educational Research Association. Dr. Grobman outlines the many facets of evaluation on the basis of her experience as a consultant on many curriculum projects and her work as an evaluator of the Biological Sciences Curriculum Study (BSCS) projects. The book is written to be used by teachers.

Haun, R. R., ed. *Science in General Education*. Dubuque, Iowa: Wm. C. Brown Co., 1960 (Toronto: Burns & MacEachern Ltd.).

This publication is an anthology concerned with general education at the college level.

Hawkins, David. "Messing About in Science". *Science and Children*, February 1965.

Children work with real things in their own way. This publication gives a vivid and detailed description of the process.

Hurd, Paul D. *Biological Education in American Secondary Schools, 1890–1960*. Baltimore: Waverly Press, 1961.

This background historical study gives a critical commentary on curriculum development and classroom and laboratory learning in the field of biological science in American high schools from 1890 to 1960. It was prepared as background material for the Biological Sciences Curriculum Study of the American Institute of Biological Sciences.

Hurd, Paul D. *New Directions in Teaching Secondary School Science*. Chicago: Rand McNally & Co., 1969 (Toronto: W. J. Gage Ltd.).

A leading science educator interprets the recent trends in secondary school science curriculum development and the perspective they provide for new directions.

Hurd, Paul D., and Gallagher, James J. *New Directions in Elementary Science Teaching*. Belmont, Cal.: Wadsworth Publishing, 1968 (paperback).

This book provides an account of recent thinking in elementary school science. A portion is given to describing and criticizing elementary science curricula such as the Science Curriculum Improvement Study (SCIS), the Elementary Science Study (ESS), and the American Association for the Advancement of Science (AAAS) program entitled Science—A Process Approach.

Kuhn, Thomas S. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press, 1962.

Kuhn develops the thesis that science advances by "scientific revolutions" in which current scientific paradigms are discarded for paradigms with more explanatory power. Kuhn uses the term *paradigm* to mean accepted examples of scientific thought and practice.

Lacey, Archie L. *Guide to Science Teaching in Secondary Schools*. Belmont, Cal.: Wadsworth Publishing, 1966 (paperback).

This is a collection of materials, resources, principles, and guidelines to assist science teachers in providing meaningful experiences designed to enhance scientific literacy. It is a handbook that alerts the reader to major problems, pitfalls, or barriers to be confronted, and suggests practical principles, paths, or resources that a teacher might utilize in arriving at his own decisions for action.

MacMillan, C.J., and McClellan, James. "Can and Should Means-ends Reasoning be Used in Teaching?". *Concepts of Teaching: Philosophical Essays*. Chicago: Rand McNally & Co., 1968 (Toronto: W. J. Gage Ltd.).

This article questions the common curriculum development rationale of designing methodology on the basis of pre-determined sequences of objectives.

Massey, Norman B. *Patterns for the Teaching of Science*, rev. ed. Toronto: The Macmillan Co. of Canada Ltd., 1969.

The novice science teacher will find this guide useful for many techniques and procedures which apply to science teaching.

Mead, Margaret, and Metraux, Rhoda. "Image of the Scientist Among High School Students: A Pilot Study". *Science* 126, no. 384 (1957).

The researchers attempt to characterize prevalent images of scientists by analysing paragraphs written by students to complete the phrases "When I think about a scientist, I think of . . .", "If I were going to be a scientist, I should like to be the kind of scientist who . . .", etc. The article concludes with recommendations for promoting "accurate" images of scientists and science with students.

Morrison, Philip. "Less May Be More". *American Journal of Physics*, June 1964.

A physicist probes for a more rewarding science program.

National Science Teachers Association. (Sullivan, J.J., and Taylor, C.W.) *Learning and Creativity: With Special Emphasis on Science*. Washington, D.C.: NEA Publications Sales, 1967.

Inquiry, individualized instruction, and independent study are the order of the day in educational philosophy. This terrain, new to both the learner and the teacher, is charted in terms of the theories of learning and of the creativity to be fostered.

National Science Teachers Association. *Theory into Action in Science Curriculum Development*. Washington, D.C.: NEA Publications Sales, 1964.

This well-known NSTA publication on science curriculum development is divided into three parts entitled, "Toward a Theory of Science Education Consistent with Modern Science", "Conceptual Schemes and the Process of Science", and "Planning a Local Action Program for Implementing Curriculum Development in Science".

National Society for the Study of Education. *Rethinking Science Education*. (59th Yearbook, Part I). Chicago: University of Chicago Press, 1960.

This book interprets trends and projects future developments in science education at both the elementary and secondary school level. This yearbook contains articles written by a large number of leading American science educators.

Ontario Curriculum Institute (now Ontario Institute for Studies in Education). *Science: An Interim Report of the Science Committee*. Toronto, 1963.

This report asked questions about science in Ontario schools and presented interim proposals.

Ontario Department of Education. *Living and Learning*. The Report of the Provincial Committee on Aims and Objectives of Education in the Schools of Ontario. Toronto: Newton Publishing, 1968.

This book is basic background reading for the educator in Ontario. For information on additional copies write to: The Publications Office, Ontario Department of Education, Mowat Block, Queen's Park, Toronto 182, Ontario.

Pella, Milton O. "Concept Learning in Science". *The Science Teacher*, December 1966.

This article discusses the place of concepts in science and defines the term *concept*.

Renner, John W., and Regan, William B. *Teaching Science in the Elementary School*. New York: Harper & Row, 1968 (Toronto: Fitzhenry & Whiteside Ltd.).

This general text on science teaching at the elementary school level emphasizes student-centred experiences and provides a sound philosophical and psychological base. It is of value to secondary school teachers.

Robinson, James T. *The Nature of Science and Science Teaching*. Belmont, Cal.: Wadsworth Publishing, 1968.

A summary of the writings of six scholars, all working scientists, is used as a basis for delineating theories about science current among those who are reaching a more sophisticated level of scientific literacy.

Romey, William D. *Inquiry Techniques for Teaching Science*. Englewood Cliffs, N.J.: Prentice-Hall Inc., 1968 Toronto: Prentice-Hall of Canada Ltd.).

This book is written primarily for student teachers but is also valuable for the experienced teacher. The first half deals with the many aspects of science teaching, both in the laboratory and in the field; the second half presents an overview of significant writings on the philosophy and methods of inquiry-teaching in science.

Schwab, Joseph J. "The Teaching of Science as Enquiry" in *The Teaching of Science*. Cambridge, Mass.: Harvard University Press, 1962 (Toronto: Saunders of Toronto Limited).

Schwab argues that science should be treated in terms of processes of disciplinary inquiry and not as a "rhetoric of conclusions". The article suggests several instructional methods to achieve this end.

Schwab, Joseph J. "What Do Scientists Do?". *Behavioral Science* 5 (1960).

This paper describes the principles of inquiry used in science. According to Schwab, principles function in inquiry by providing the terms in which problems are formulated; by dictating the data required and, therefore, delimiting procedures necessary to obtain the data; and, finally, by providing the terms in which data are interpreted and new knowledge formulated.

Schwab, Joseph J., and Brandwein, Paul F. *The Teaching of Science*. Cambridge, Mass.: Harvard University Press, 1962. (Toronto: Saunders of Toronto Limited).

The two authors suggest that schools can be places for fluid inquiry in which a child's search parallels the research of a scientist.

Sund, Robert B., and Trowbridge, Leslie W. *Teaching Science by Inquiry in the Secondary School*. Columbus, Ohio: Charles E. Merrill, 1967.

This wide-ranging book on the many aspects of science teaching is written for the novice secondary school teacher.

Toulmin, Stephen. *The Philosophy of Science*. (Harper Torchbook) New York: Harper and Row, 1960 (Toronto: Fitzhenry & Whiteside Ltd.).

This discussion centres on the fundamental nature of scientific investigation and the meaning of "discovery" in science. It is designed to give students of philosophy an insight into scientific thought and endeavour.

Victor, Edward, and Lerner, Marjorie S. *Readings in Science Education for the Elementary School*. New York: Macmillan Co., 1967 (Galt, Ontario: Collier-Macmillan Canada, Ltd.).

This compendium of papers relates to the teaching of science in elementary schools. A wide variety of topics is included: the role of science in elementary schools, objectives of elementary science, planning and organizing the science program, evaluation, pre-service and inservice training of teachers, inquiry processes in science education. Major elementary science curriculum projects are also described.

Wastnedge, E.R., "Children are People". *The Crucible*, Spring 1968.

The article describes the philosophy underlying open inquiry in the Nuffield Junior Science Project.

Whitehead, Alfred N. *The Aims of Education and Other Essays*. New York: The Free Press, 1967 (Galt, Ontario: Collier-Macmillan Canada, Ltd.).

This collection of essays by an outstanding philosopher is excellent background reading for teachers.

Woodburn, John H., and Osburn, Ellsworth S. *Teaching the Pursuit of Science*. New York: Macmillan Co., 1965 (Galt, Ontario: Collier-Macmillan Canada, Ltd.).

The middle hundred pages describe the evolution of science curricula in the U.S.A. and the present place of science in the school program.

Adler, M. *Some Implications of the Theories of Jean Piaget and J.S. Bruner for Education.* Toronto: Research Department, Board of Education for the City of Toronto, 1963.

This monograph outlines both arguments for, and against, the theories of Piaget and Bruner. It cites specific research evidence which backs up some claims and refutes others.

Ausubel, D.P. *Learning Theory and Classroom Practice.* Toronto: Ontario Institute for Studies in Education, 1967.

Teachers will find that this publication provides a general overview of the value of learning theory.

Ausubel, D.P. and Robinson, F.G. *School Learning.* New York: Holt, Rinehart & Winston, 1969. (Toronto: Holt, Rinehart & Winston of Canada Ltd.).

This book contains information on the application of Ausubel's theory to classroom practice particularly at the junior and senior high school levels.

Bruner, Jerome S. *The Process of Education.* Cambridge, Mass.: Harvard University Press, 1960. (Toronto: Saunders of Toronto Limited).

One of the best known books on education by this leading psychologist.

Connelly, Michael. "*Curriculum Development and Implied Conceptions of Knowledge Structure*". Toronto: Ontario Institute for Studies in Education.

In this unpublished paper, Dr. Connelly compares the implied conceptions of disciplinary structure of three psychologists—Gagné, Ausubel and Bruner.

Friedlander, B.Z. "A Psychologist's Second Thought on Concepts, Curiosity, and Discovery in Teaching and Learning". *Harvard Educational Review 35* (Winter 1965).
Friedlander, B.Z. "Today's Innovations in Teaching". *NEA Journal*, March 1966.

These articles constitute a healthy balance to the oversimplified views and little understood notions of how to induce independent activities among children.

Gagné, Robert M. *The Conditions of Learning.* New York: Holt, Rinehart & Winston, 1965. (Toronto: Holt, Rinehart & Winston of Canada Ltd.).

This is a useful conceptualization of the learning process. It offers suggestions for both the diagnosis and the remedy of learning difficulties.

Ginsburg, H. and Opper, S. *Piaget's Theory of Intellectual Development: An Introduction.* Englewood Cliffs, New Jersey: Prentice-Hall, Inc. 1969. (Toronto: Prentice-Hall of Canada Ltd.).

The book contains a relatively simple outline of Piaget's theory. Although some reference is made to the application of his theory to classroom practice, it concentrates upon the basic elements of the theory.

Grooms, M.A. *Perspectives on the Middle School.* Columbus, Ohio: Charles E. Merrill, 1967.

A description of the interests, development, and maturity of students of intermediate age is coupled with an outline of school organizations and resources that meet the needs of this age group.

Hyde, D.M.G. *Piaget and Conceptual Development.* London: Holt, Rinehart & Winston, 1970. (Toronto: Holt, Rinehart & Winston of Canada Ltd.).

This book contains a more advanced interpretation of Piaget's theory than does the book by Ginsburg and Opper. It discusses the growth of concepts as the child progresses through the stages of development and gives emphasis to the growth of intellect and "knowing".

Isaacs, Susan. *Intellectual Growth in Young Children.* London: Routledge and Kegan Paul, 1930. (Toronto: General Publishing Co. Ltd.).

Mrs. Isaacs discusses discovery, reasoning, and thought from her three-year records at the Malting House School.

Laurendeau, Monique, and Pinard, Adrien. *Casual Thinking in the Child.* Montreal: Institut de Recherches Psychologiques, 1962.

More empirical investigations like this are necessary in order to illustrate the developmental nature of cognitive development. Since some notion of cause and effect is central to the study of science, it is important for science teachers to understand how this method of reasoning develops in children and adults. This book is easily understood, but teachers should know that we have not yet been able to derive teaching sequences that are isomorphic with the learning process.

Metropolitan Toronto School Board Study of Education Facilities. *SEF E2, Educational Specifications and User Requirements for Intermediate Schools.* Toronto: McGraw-Hill Ryerson Ltd., 1969.

Part 1 of this publication contains a condensation of recent research and literature concerning the development of the pre-adolescent and the adolescent. It gives a sensitive description of the students, their world and their schooling.

Piaget, Jean. *The Child's Conception of Physical Casuality.* London: Routledge and Kegan Paul, 1930. (Toronto: General Publishing Co. Ltd.).

This classic study shows how adults and children view the world differently.

Piaget, Jean. *Science of Education and the Psychology of the Child.* New York: Orion Press, 1970.

This is one of the few books in which Piaget outlines the educational implications of his developmental theory. In it he suggests an approach to the science of education which reflects work being done in a very large project in England at Nuffield.

Stone, L. Joseph, and Church, Joseph. *Childhood and Adolescence.* New York: Random House Inc., 1957 (Toronto: Random House of Canada Ltd.).

This general textbook treats three aspects of adolescent development—physical, intellectual and societal.

Tyler, Ralph W. *Basic Principles of Curriculum and Instruction.* Chicago: University of Chicago Press, 1969. (Paperback).

This book describes the learner's life outside the school, objectives of subject specialists, psychology of learning, and certain criteria concerning curriculum development as well as some aspects of evaluation.

Atkin, J. Myron. "Behavioral Objectives in Curriculum Design: A Cautionary Note". *The Science Teacher*, May 1968.

A note of caution is sounded concerning the underlying assumptions and broad questions of educational policy inherent in the use of behavioural objectives.

Bloom, Benjamin S., ed., et al. *Taxonomy of Educational Objectives: The Classification of Educational Goals.* New York: David McKay & Co. (Toronto: Longmans Canada Ltd.). Handbook I: Cognitive Domain (1956); Handbook II: Affective Domain (1964).

This well-known series on the classification of educational goals is a valuable reference for the serious student of education.

Eiss, Albert F. "The NSTA Conferences on Scientific Literacy". *The Science Teacher*, May 1968.

This publication includes a report on several conferences held by the NSTA Committee on College Relations and others held by the National Science Supervisors Association on the topic of scientific literacy. A list of desirable objectives in the cognitive and affective domains is given.

Gideonse, Hendrick D. "Behavioral Objectives: Continuing the Dialogue". *The Science Teacher*, January 1969.

The writer regards the development of behavioural objectives as the generation of criterion measures.

Mager, R. F. *Preparing Instructional Objectives.* Palo Alto, Cal.: Fearon Publishers Inc., 1962. (Toronto: Clarke, Irwin & Company Ltd., paperback).

This short programmed text on behavioural objectives is mainly concerned with three issues: (1) selection of written objectives in performance terms, (2) identification of minimum acceptable performances for a given objective, and (3) identification of appropriate tests for evaluation of given objectives.

National Science Teachers Association. (Eiss, Albert F., and Harbeck, Mary Blatt). *Behavioral Objectives in the Affective Domain.* Washington, D.C.: NEA Publications Sales, 1969.

This monograph was prepared by the National Science Supervisors Association, a section of the NSTA, to assist science teachers in working toward a better understanding of educational objectives in the affective domain.

National Science Teachers Association. (Koran, John J., et al.) *How to Use Behavioral Objectives in Science Instruction.* Washington, D.C.: NEA Publications Sales, 1969.

In order to make effective curriculum decisions, the teacher needs many aids. This monograph describes one aid—behavioural objectives—discusses their use, and shows their relationship to general instruction.

Science Curriculum Resource Publications

The following books will be found useful sources of ideas in assisting the teacher to develop his own curriculum.

Abraham, Norman, et al. *Interaction of Man and the Biosphere*. Chicago: Rand McNally & Co., 1970. (Toronto: W. J. Gage Ltd.).
A course in life science based upon an inquiry system of teaching and learning. This course is designed to precede that entitled *Interaction of Matter and Energy*.

Abraham, Norman, et al. *Interaction of Matter and Energy*. Chicago: Rand McNally & Co., 1968. (Toronto: W. J. Gage Ltd.).
A physical science program which attempts to give the students an understanding of the processes of science and of the acquisition of fundamental scientific knowledge. Laboratory investigations are used throughout. A teachers' edition of the text is available.

*Anastasiou, C.J., et al. *Reading About Science 1*. Toronto: Holt, Rinehart and Winston of Canada Ltd., 1968.
This is the first book in a generously illustrated series of background readers about scientific discoveries. See Forster, et al. for Volume 2, and Woodrow, et al. for Volume 3.

*Andrews, W.A., et al. *Science 10*. Toronto: The Copp Clark Publishing Company, 1967.
The second of a two-book series on general science, this publication contains both descriptive material and instructions for student-conducted laboratory experiments. See Casson, et al. for *Science 9*.

Association for Supervision and Curriculum Development. (Haney, R.E.) *The Changing Curriculum: Science*. Washington, D.C.: NEA Publications Sales, 1966.
This publication takes into account the difficulty experienced by teachers in choosing programs, innovations, and materials from the bewildering array available to them. It describes the major new programs and attempts to evaluate them for the teacher, using a series of criteria.

*Biological Sciences Curriculum Study. *Biological Science: An Inquiry into Life*, 2nd ed. New York: Harcourt, Brace & World, 1968. (Toronto: Longmans Canada Ltd.).
One of three major curriculum organizations in the biological sciences prepared by the BSCS program, this version, commonly called "the yellow version", gives more emphasis to the cell than do the other two versions. A teachers' edition of the textbook and a laboratory manual for the 2nd edition are available. Tests will probably be available in the future.

*Biological Sciences Curriculum Study. *Biological Science: Molecules to Man*, rev. ed. Boston: Houghton Mifflin Co., 1968. (Toronto: Thomas Nelson & Sons (Canada) Ltd.).
One of three major curriculum organizations in the biological sciences prepared by the BSCS program, this version, commonly called "the blue version", gives more emphasis to molecular biology than do the others. A teachers' edition is available for the 2nd edition. Standardized achievement tests are also available.

Biological Sciences Curriculum Study. *Biological Science: Patterns and Processes*. New York: Holt, Rinehart & Winston, 1966. (Toronto: Holt, Rinehart and Winston of Canada Ltd.).
This "Special Materials Program" was designed for the slow readers of Grade 10. It is a workbook containing several exercises of programmed learning and other laboratory activities.

*Biological Sciences Curriculum Study. *Biologie: des molécules à l'homme*. Montreal: Centre de Psychologie et de Pédagogie, 1966.
C'est une édition en langue française de "Biological Science: Molecules to Man". Ce manuel de biologie répond aux exigences actuelles de la science pour la fin du secondaire ou le pré-universitaire.

Biological Sciences Curriculum Study. (Schwab, Joseph J., Supervisor). *Biology Teachers' Handbook*. New York: John Wiley & Sons, 1963. (Toronto: John Wiley & Sons Canada Ltd.).
A reference book for biology teachers, this publication provides background information on the yellow, green, and blue versions of the BSCS texts.
In addition to a discussion of the inquiry approach to teaching, considerable basic material in the area of chemical bonds and biochemistry is provided.

*Biological Sciences Curriculum Study. *High School Biology*, 2nd ed. Chicago: Rand McNally & Co., 1968. (Toronto: W. J. Gage Ltd.).
One of three major curriculum organizations in the biological sciences prepared by the BSCS program, this version commonly called "the green version", gives more emphasis to ecological studies than do the others. A teachers' guide for the 2nd edition is also available.

*Brackenborough, E.F., et al. *The Methods of Science*. Toronto: Clarke, Irwin & Company Ltd. Book 1 (1964); Book 2 (1965); Book 3 (rev. ed., 1961); Book 4 (1962).
Both descriptive material and instructions for student-conducted laboratory experiments are included in this four-book series on general science. A teachers' manual is available for each text.

Brandwein, Paul F., et al. New York: Harcourt, Brace & World, 1968. (Toronto: Longmans Canada Ltd.).
Energy: Its Forms and Changes
Life: Its Forms and Changes
Matter: Its Forms and Changes
This series of three texts could serve as resource books even though they often go into areas usually reserved for later grades. An effort is made to relate studies to everyday experience. There are experiments in the text.

Brandwein, Paul F., et al. *Teaching High School Science: A Book of Methods*. New York: Harcourt, Brace & World, 1958. (Toronto: Longmans Canada Ltd.).
This is a comprehensive resource book on the many aspects of high school science teaching.

*Bruce, V.N., and Carter, A.H. *Science for Secondary Schools, Book 1*. Toronto: Sir Isaac Pitman (Canada) Ltd., 1961.
The first of a two-book series on general science, this book includes both descriptive material and instructions for student-conducted laboratory experiments. See Carter and Earl for Book 2.

*Cannon, G.H., et al. *Labtext in Science, Book 1*. Toronto: The Copp Clark Publishing Company, 1968.
This problem-oriented program of laboratory investigations in the field of physical science includes a minimum amount of descriptive material. A teachers' resource book is also available.

*Carter, A.H., and Earl, E.L. *Science for Secondary Schools, Book 2*. Toronto: Sir Isaac Pitman (Canada) Ltd., 1962.
Both descriptive material and instructions for student-conducted experiments are included in the second book of this two-book series on general science. See Bruce and Carter for Book 1.

*Casson, R.G., et al. *Science 9*. Toronto: The Copp Clark Publishing Company, 1965.
The first of a two-book series on general science, this publication includes both descriptive material and instructions for student-conducted laboratory experiments. See Andrews, et al. for *Science 10*.

Clark, Robert A., et al. *Biology by Inquiry*. London: Heinemann Educational Books Ltd. Book 1 (1968); Book 2 (1970). (Toronto: Bellhaven House Ltd.).
These two books, derived from work done by the Nuffield Project, outline a series of student investigations in the biological sciences. They are written to enable the student to proceed independently.

*Cole, L.A., and Saxton, P., Toronto: The Macmillan Co. of Canada Ltd.
Investigations in Science (1968)
Investigating our World (1970)
These texts on general science include both descriptive material and instructions for student-conducted laboratory experiments.

*Cournoyer, L., and Garon, O. *Biologie*. Montreal: Editions H.M.H., 1968. (Toronto: Oxford University Press).
Un manuel de biologie humaine et de ses applications dans la vie quotidienne. Il suggére de nombreuses expériences de laboratorie qui suscitent l'esprit d'observation et de recherche. Ce volume es abondamment illustré en noir et en couleur.

*Earth Science Curriculum Project. *Investigating the Earth*. Boston: Houghton Mufflin Co., 1967. (Toronto: Thomas Nelson & Sons (Canada) Ltd.).
This book provides a program of studies in earth science, developed under the sponsorship of the American Geological Institute and supported by the National Science Foundation. A Laboratory Supplement and an extensive Teachers' Guide are available.

Educational Research Council of America. *Life Science Investigation, Man and the Environment*. Boston, Mass.: Houghton Mifflin Company, 1971. (Toronto: Thomas Nelson and Sons (Canada) Ltd.).
Biological principles are studied in the context of student investigations of the environment. A Teacher's edition of the text is also available.

*Equipe IPS. *Initiation aux sciences physiques.* Montreal: Institut de Recherches Psychologiques, 1969.

C'est une édition en langue française de l'Introductory Physical Science. Ce cours repose sur une idée maîtresse qui se raméne à l'appui du modéle atomique de la matiére.

Fitzpatrick, F.L., et al. *Living Things*, 4th ed. New York: Holt, Rinehart & Winston, 1970. (Toronto: Holt, Rinehart and Winston of Canada Ltd.).

Designed for general education, this book is less apt to overwhelm the student by its size and vocabulary than many modern texts.

*Forster, Mary, et al. *Reading About Science 2.* Toronto: Holt, Rinehart and Winston of Canada Ltd., 1969.

The second book in a series of generously illustrated background readers on scientific discoveries. See Anastasiou, et al. for Volume 1 and Woodrow, et al. for Volume 3.

*Hallman, M., et al. *Intermediate Science.* Toronto: Holt, Rinehart and Winston of Canada Ltd. Book 1 (1962); Book 2 (1962).

This four-book series on general science includes both descriptive material and instructions for student-conducted laboratory experiments. See Taylor, et al. for Books 3 and 4.

*Hedges, H.G., et al. *Explorations scientifiques.* Toronto: W. J. Gage Ltd. Livre 1 (1964); Livre 2 (1965).

C'est une édition en langue française de *Science Activities*. Ces deux volumes traitent des sciences en général. La methode employée àcet effetfait intervenir la présentation de données scientifiques d'une part et, d'autre part, l'expérimentation et la réflexion sur les résultats de ce travail.

*Hedges, H.G., et al. *Science Activities.* Toronto: W. J. Gage Ltd. Book 7 (1961); Book 8 (1961).

This two-book series on general science includes both descriptive material and instructions for student-conducted laboratory experiments.

Herron, W.B., and Palmer, N.P. *Matter, Life and Energy*. Chicago: Lyons and Carnahan, 1965. (Toronto: McGraw-Hill Ryerson Ltd.).

This well illustrated survey book has post-chapter summaries and open-ended activity sections. A Study Guide and Laboratory Activities book as well as a Teacher's Guide, can also be purchased.

Hone, Elizabeth B., et al. *Teaching Elementary Science: A Sourcebook for Elementary Science.* New York: Harcourt, Brace & World, 1962. (Toronto: Longmans Canada Ltd.).

This is a useful resource book on many aspects of teaching science in the elementary school.

*Hughes, T.R., et al. Toronto: Thomas Nelson & Sons (Canada) Ltd., 1970.
Working with Matter
Working with Energy

These publications contain outlines of numerous student experiments and problems in the physical sciences. Teacher's editions of both books are available.

Intermediate Science Curriculum Study (Ernest Burkman, Project Director). Palo Alto, Cal.: Silver Burdett Company. (Toronto: GLC Educational Materials and Services Limited).
Probing the Natural World, Vol. 1 (1970)
Probing the Natural World, Vol. 2 (1971)

An intensive student conducted laboratory investigation of science concepts is outlined in the program. Both volumes are organized about content and process themes. A Teacher's edition of the text and student and teacher editions of an accompanying record book are available. The development of the program was supported by the National Science Foundation.

*Introductory Physical Science Group. *Introductory Physical Science.* Englewood Cliffs, N.J.: Prentice-Hall Inc., 1967. (Toronto: Prentice-Hall of Canada Ltd.).

This course in physical science, sponsored by Educational Services Incorporated and supported by the National Science Foundation, attempts to give students an insight into the means by which scientific knowledge is acquired through a series of laboratory investigations designed to build evidence for an atomic model of matter.

Joseph, Alexander, et al. *Teaching High School Science: A Sourcebook for the Physical Sciences.* New York: Harcourt, Brace & World, 1961. (Toronto: Longmans Canada Ltd.).

This comprehensive resource book discusses the teaching of physical sciences in high school.

*Lang, H.M., and Speed, F.M. *Basic Science, Book 2.* Toronto: The Macmillian Co. of Canada Ltd., 1968.

One of a two-book series on general science, this book contains both descriptive material and instructions for student-conducted laboratory experiments. See Speed, and Lang, for Book 1.

Laybourn, K., and Bailey, C.H. *Teaching Science to the Ordinary Pupil.* London: University of London Press, 1957. (Toronto: Musson Book Company).

The authors show how many aspects of science teaching can be treated experimentally, with the main emphasis on practical work by the pupils themselves. The book shows that materials and apparatus familiar with everyday life are often the best medium.

*Lead, H.D., and Rivard, R.F. *Experiments in Elementary Science.* Toronto: Sir Issac Pitman (Canada) Ltd. 1965.

This book includes both descriptive material and instructions for student-conducted laboratory experiments in the physical sciences.

Lockard, J.D., ed. *Report of the International Clearinghouse on Science and Mathematics Curricular Developments.* (Joint Project of the American Association for the Advancement of Science and the Science Teaching Center, University of Maryland.

This reference book is an annual international report on all current curriculum projects recorded in science and mathematics. The following aspects are noted: name of projects director and address, purpose of project, publishers, free materials, published materials, intended grade level(s), future plans.

Marean, John H., and Ledbetter, Elaine W. *Physical Science: A Laboratory Approach.* Menlo Park, Cal.: Addison-Wesley Publishing Co. Inc., 1968. (Toronto: Addison-Wesley (Canada) Ltd.).

This physical science course gives the student an understanding of the structure of matter and the nature of energy through an organized series of meaningful experiments. A teachers' edition of the text and laboratory record books are available. Sample tests are also published.

Morholt, Evelyn, et al. *Teaching High School Science: A Sourcebook for the Biological Sciences*, 2nd ed. New York: Harcourt, Brace & World, 1966. (Toronto: Longmans Canada Ltd.).

This comprehensive resource book focuses on teaching the biological sciences in high school.

National Science Teachers Association. *Environmental Education for Everyone: Bibliography of Curriculum Materials for Environmental Studies.* Washington, D.C.; NEA Publications Sales, 1970.

National Science Teachers Association. (Hurd, Paul DeHart). *How to Teach Science Through Field Studies.* Washington, D.C.; NEA Publications Sales, 1965.

This monograph deals with the place of field studies in the new science curriculum. It covers such aspects as how to plan a field studies program, how administration can help, and how to deal with the negative attitudes of some administrators towards field studies.

Nuffield Foundation. *Combined Science.* London: The Longman Group, 1970. (Toronto: Longmans Canada Ltd.).

A program of studies for 11 to 13 year old children in which topics in biology, chemistry and physics have been intertwined.

Nuffield Foundation Science Teaching Project. London: Longmans Green and Co. Ltd., 1968. (Toronto: Longmans Canada Ltd.).

Biology
A program of studies in biology for 11 to 16 year old children. Four different student texts and accompanying teachers' guides are available. A Canadian version of the first student text to this series is also available from this publisher.

Chemistry
A program of studies in chemistry for 11 to 16 year old children. Student books which outline a basic course of study and a number of optional topics are published. Teacher resource books and a series of Chemistry Background Books for students are also available.

Physics
A program of studies in physics for 11 to 16 year old children. Five question books have been prepared for student use. A number of teacher resource books are also available.

Ontario Institute for Studies in Education. *OISE Science Units for Elementary School.* Kingston: Ontario Teachers' Federation, 1465 Princess Street.
"Matter" (no prerequisites);
"Measurement" (to follow "Matter");
"Microscopy" ("Matter" is prerequisite);
"Comparing Animals" (no prerequisites);
"Work and Energy" ("Matter" and "Measurement" are prerequisites);
"Temperature, Heat, and Energy" (to follow "Work and Energy");
"Some Effects of Heat on Matter" (to follow "Temperature, Heat, and Energy").

Three additional units are currently under development. Each of these units consists of a teacher's manual and a kit of equipment for use by approximately forty pupils. No written materials have been prepared for pupil use. The units are designed to serve as samples to assist teachers who wish to develop their own units of investigation consistent with the philosophy of science education as outlined in Part II of *New Designs for Learning: Highlights of the Reports of the Ontario Curriculum Institute, 1963–1966*, edited by Brian Burnham and published for OISE by the University of Toronto Press in 1967.

Otto, J.H., and Towle, A. *Modern Biology*, 7th ed. New York Holt, Rinehart & Winston, 1969. (Toronto: Holt, Rinehart and Winston of Canada Ltd.).

A general biology textbook supplemented by student laboratory manuals, tests and a teacher's guide.

Oxenhorn, J.M. and Idelson, M.N. New York: Globe Book Company. (Toronto: The Book Society of Canada Limited).
Pathways in Science 1. (1968) A series of four books—Biology, Chemistry, Physics, Earth Sciences.
Pathways in Science 2. (1969) A series of four books—Biology, Chemistry, Physics, Earth Sciences.
Pathways in Science 3. (1970) A series of four books—Biology, Chemistry, Physics, Earth Sciences.

This series of twelve books is written specifically for below-average ability children of the junior high level. The reading level is Grade 5. Many techniques are used to appeal to these children.

*Rasmussen, W.H., and Schmid, M.C. *Developing Science Concepts in the Laboratory.* Toronto: Prentice-Hall of Canada Ltd. 1968.

Numerous student experiments in the field of both physical and biological sciences are outlined in this book.

Saterstrom, Mary Horkeimer. *Educators' Guide to Free Science Materials.* Randolph, Wisconsin: Educators' Progress Service.

This book is published annually. It is devoted exclusively to free science materials based on the cross-media approach. It offers a complete, up-to-date, annotated schedule of selected, currently available, free audio-visual and other science curricular enrichment aids.

*Spafford, R.G., and Robinson, W.D.T. *Elements of Science.* Toronto: Sir Isaac Pitman (Canada) Ltd., 1965.

This book includes both descriptive material and instructions for student-conducted laboratory experiments in the physical sciences.

*Speed, F.M., and Lang, H.M. *Basic Science, Book 1.* Toronto: The Macmillian Co. of Canada Ltd., 1968.

One of a two-book series on general science, this publication contains both descriptive material and instructions for student-conducted laboratory experiments. See Lang, H.M., and Speed, F.M., for Book 2.

*Taylor, S., et al. *Intermediate Science.* Toronto: Holt, Rinehart and Winston of Canada Ltd. Book 3 (1962); Book 4 (1962).

This four-book series on general science includes both descriptive material and instructions for student-conducted laboratory experiments. See Hallman, et al. for Books 1 and 2.

Thurber, Walter A., Kilburn, Robert E., Boston: Allyn and Bacon Inc., (Toronto: The Macmillan Company of Canada Ltd., 1969).
Exploring Earth Science (Canadian Edition)
Exploring Life Science (Canadian Edition)
Exploring Physical Science (Canadian Edition)

A three-year program of studies in science for children in the Intermediate Division.

Weinberg, S.L. *Biology: An Inquiry Into the Nature of Life.* Rockleigh, N.J.: Allyn & Bacon Inc., 1966. (Toronto: The Macmillan Co. of Canada Ltd.).

A blending of traditional and inquiry aspects of biology. The laboratory manual contains many exercises.

Weisbruch, Fred T., et al. *Patterns and Processes of Science.* Boston: D.C. Heath. Laboratory Text No. 1 (1969); No. 2 (1969); No. 3 (1968). (Toronto: D.C. Heath, Canada).

A three-year program organized so as to give emphasis to the processes of scientific investigation. Student laboratory experimentation is a major component of this program, which is concerned mainly with the physical sciences.

Wong, Harry K., Dolmatz, Melvin S., Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1971. (Toronto: Prentice-Hall of Canada Ltd.).
Ideas and Investigations in Science, Biology
Ideas and Investigations in Science, Physical Science

These books present an investigation of scientific concepts designed especially for the non-academic student. A teacher's manual is available for each book.

Woodrow, Janice, et al. *Reading About Science 3.* Toronto: Holt, Rinehart and Winston of Canada Ltd., 1970.

This is the third book in a generously illustrated series of background readers about scientific discoveries. See Anastasiou, et al. for Volume 1 and Forster, et al. for Volume 2.

The American Biology Teacher, published monthly September through May by the National Association of Biology Teachers, 1420 N Street N.W., Washington, D.C. 20005.

The Australian Science Teachers Journal, published May, August, and November by the Australian Science Teachers Association, School of Education, Macquarie University, North Ryde, N.S.W. 2113, Australia.

Canadian Audubon, published January, March, May, September, and November by the Canadian Audubon Society, 46 St. Clair Avenue East, Toronto 290, Ontario.

Canadian Chemical Education, published October, January, and April by the Chemical Institute of Canada, 151 Slater Street, Suite 906, Ottawa 4, Ontario.

The Canadian Scientist, published six times a year by Pergamon of Canada Ltd., 207 Queen's Quay West, Toronto 117, Ontario.

Chemistry, published monthly, except combined issues in July and August, by the American Chemical Society, 20th and Northampton Street, Easton, Pa. 18042.

Chemistry in Canada, published monthly by the Chemical Institute of Canada, 151 Slater Street, Ottawa 4, Ontario.

Commission on Science Education Newsletter, published by the American Association for the Advancement of Science, 1515 Massachusetts Avenue N.W., Washington, D.C. 20005.

The Crucible, Published eight times a year by the Science Teachers' Association of Ontario, 252 Bloor Street West, Suite 904, Toronto, Ontario.

Education in Chemistry, published in January and alternate months by the Royal Institute of Chemistry, 30 Russell Square, London WC1B 5DT, England, and The Chemical Society, Burlington House, London W1V OBN, England.

Environmental Science and Technology, published monthly by the American Chemical Society, 20th and Northampton Streets, Easton, Pa. 18042.

Journal of Biological Education, published quarterly for the Institute of Biology by Academic Press, Berkeley Square House, Berkeley Square, London W1X 6BA, England.

Journal of Chemical Education, published monthly by the Division of Chemical Education of the American Chemical Society, 20th and Northampton Streets, Easton, Pa. 18042.

Journal of Research in Science Teaching, published quarterly by John Wiley & Sons, Inc., 605 Third Avenue, New York, N.Y. 10016.

Le Jeune Scientifique, le volume annuel commence en octobre et se termine en ami, soit 8 numéros. Les Presses de l'Université du Québec, 2525, boul. Laurier, Sainte-Foy, Québec 10, Québec.

Natural History, published monthly October through May, bi-monthly June to September, by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024.

Natural Science in Schools, published spring, summer, and autumn by George Philip and Son Limited, Victoria Road, London N.W. 10, England.

Nature, published weekly by Macmillan (Journals) Ltd., 4 Little Essex Street, London W.C. 2, England.

New Scientist, published weekly by New Science Publications, 128 Long Acre, London W.C. 2, England.

Physics in Canada, published seven times a year by the University of Toronto Press for the Canadian Association of Physicists, Suite 903, 151 Slater Street, Ottawa 4, Ontario.

The Physics Teacher, published monthly September through May by the American Association of Physics Teachers, 3110 Elm Avenue, Baltimore, Md. 21211.

Physics Today, published monthly by the American Institute of Physics, Ind., at Mack Printing Company, Easton, Pa.

Scholastic Teacher, published weekly by Scholastic Magazines, Inc., 50 West 44th Street, New York, N.Y. 10036.

School Science and Mathematics, published monthly October through June by the Central Association of Science and Mathematics Teachers, Inc., Curtis Reed Plaza, Menasha, Wisconsin.

The School Science Review, published in September, December, March, and June by John Murray, 50 Albemarle Street, London, England.

Science, published weekly by the American Association for the Advancement of Science, 1515 Massachusetts Avenue N.W., Washington, D.C. 2005.

Science Affairs, published eight times a year by Youth Science Foundation, Suite 302, 151 Slater Street, Ottawa, Ontario.

Science and Children, published monthly September through December and February through May by the National Science Teachers Association, 1201 Sixteenth Street N.W., Washington, D.C. 20036.

Science and Technology, published monthly by International Communications, Inc., 205 E. 42nd Street, New York, N.Y. 10017.

Science Dimension, published six times a year by the Information Services Office of the National Research Council of Canada, Ottawa 7, Ontario.

Science Education, published in February, March, April, October, and December by Interscience Publishers, a division of John Wiley & Sons, Inc., 605 Third Avenue, New York, N.Y. 10016.

Science Forum, published every second month by Science Forum, printed and distributed by University of Toronto Press, University of Toronto, Toronto 181, Ontario.

Science in Action, published fortnightly during term by New Science Publications, 128 Long Acre, London W.C. 2, England.

Science Journal, published monthly by IPC Business Press Ltd., Dorset House, Stamford Street, London S.E. 1, England.

Science News, published weekly by Science Service, Inc., 1719 N Street N.W., Washington, D.C. 20036.

Science Policy News, published bi-monthly by the Science Foundation Ltd., Benjamin Franklin House, 36 Craven Street, London W.C. 2, England.

The Science Teacher, published monthly September through May by the National Science Teachers Association, 1201 Sixteenth Street N.W., Washington, D.C. 20036.

Science Teaching Equipment, published by Milton Publishing Ltd., 28 Craven Street, London W.C. 2, England.

Science World, published weekly September through May by Scholastic Magazines Inc., 50 West 44th Street, New York, N.Y. 10036.

Scientific American, Published monthly by Scientific American, Inc., 415 Madison Avenue, New York, N.Y. 10017.

Sci-Tech News, published spring, summer, fall, and winter by Burt Printing Co., Inc., Graphic Arts Center, Memorial Industrial Park, Springfield, Mass. 01104.

A Film Catalogue listing films available on loan free of charge from the Ontario Department of Education may be obtained from:

Learning Materials Service Unit,
Curriculum Branch,
Ontario Department of Education,
559 Jarvis Street,
Toronto 285, Ontario.

A number of boards of education in Ontario now maintain film libraries to serve teachers in their respective jurisdictions. Teachers employed by these boards should obtain the films from their local film library rather than from the Learning Materials Service Unit of the Ontario Department of Education.

Additional films may be obtained from the following Canadian Distributors:

B.B.C. Film Sales,
135 Maitland Street, Toronto 284.

Canadian Bankers' Association,
50 King Street West, Toronto 105.

Canadian Broadcasting Corp.,
P.O. Box 55, Terminal "A", Toronto 1.

Canadian Film Institute,
1762 Carling Avenue, Ottawa 13.
Agents for:
Educational Development Centre,
Indiana University,
Syracuse University,
Town and Country Productions,
Virginia State University.

Careers Research and Advisory Centre,
25 St. Andrew Street, Cambridge, England.

Carman Educational Films,
Pine Grove, Ontario.
Agents for: Gateway

Educational Film Distributors,
191 Eglinton Avenue East, Toronto 315.
Agents for:
Churchill Films,
International Film Bureau,
Silva,
SVE.

Encyclopedia Britannica Films,
151 Bloor Street West, Toronto 189.

Ontario Educational Communications Authority,
1670 Bayview Avenue, Toronto 298.

W. J. Gage Ltd.,
1500 Birchmount Road, Scarborough.
Agents for: BSCS Filmloops.

Griffin Press Ltd.,
455 King Street West, Toronto 135.
Agents for: Weston Wood.

Holt, Rinehart and Winston of Canada,
833 Oxford Street, Etobicoke.
Agents for:
Bailey Films,
Film Associates of California,
Holt, Rinehart & Winston Inc.

International Tele-Films Enterprises,
120 Wellington Street West, Toronto 116.
Agents for:
Barr Films,
Cahill Films,
Columbia University,
Institute for Development of Educational Activities
Neubacher-Vetter.

International Business Machines,
1150 Eglinton Avenue East, Don Mills 402.

JACDA Films Inc.,
1411 rue Crescent, Suite 404a Montréal 107.

Key Film Productions,
137 Wellington Street West, Toronto 129.

Longmans Canada Ltd.,
55 Barber Greene Road, Don Mills.
Agents for:
BSCS Filmloops and Inquiry Slides for Daylight Blackboard Projection.

Marlin Motion Pictures Ltd.,
47 Lakeshore Road East, Port Credit.
Agents for: Korty, Sterling.

McGraw-Hill Ryerson Ltd.,
330 Progress Avenue, Scarborough.

Modern Talking Pictures,
1875 Leslie Street, Don Mills 404.
Agents for:
Chemical Education Materials Study.

Moreland-Latchford Productions,
43 Dundas Street East, Toronto 205.

National Film Board,
1 Lombard Street, Toronto 210.

Ontario Teachers' Federation,
1260 Bay Street, Toronto 185.

Penn State University,
University Park, Pennsylvania U.S.A.

Reason Associates,
4 New Street, Toronto 185.

Sovereign Film Distributors,
277 Victoria Street, Toronto 200.
Agents for:
Coronet Films,
Walt Disney Films.

Trent University,
Peterborough, Ontario.

Universal Education and Visual Arts,
151 Bloor St. W., 4th Floor, Toronto 189.

Visual Education Centre,
95 Berkeley Street, Toronto 229.
Agents for: American Cancer Society.

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